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SECOND EDITION

DOS UNDOCUMENTED

A PROGRAMMER'S GUIDE TO RESERVED MS-DOS® FUNCTIONS AND DATA STRUCTURES

EXPANDED TO INCLUDE MS-DOS 6, NOVELL DOS, AND WINDOWS™ 3.1

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Undocumented DOS
Second Edition

A Programmer's Guide to Reserved MS-DOS® Functions and Data Structures

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CONTENTS

CHAPTER 8 (continued)

PREFACE

This second edition of *Undocumented DOS* is totally different from the first edition which appeared three years ago. In addition to several new chapters on the interface between DOS and Windows, on "other DOSes," and on disassembling DOS code, chapters have been completely overhauled not only to accommodate MS-DOS 5.0/6.0 and Microsoft's forthcoming "Chicago" operating system (DOS 7 and Windows 4) but also to reflect what we hope is a far more sophisticated understanding of DOS internals, and of the role of undocumented interfaces in the software industry.

DOS? In the 1990s?!

But what's the point of a new book on DOS? This is the 1990s, right? Windows programs are outselling DOS programs. Almost all new development of commercial products is targeting Windows rather than plain vanilla DOS. Having produced the book *Undocumented Windows*, isn't a return to DOS with its line commands and boring user interface a form of childish regression?

Not at all. First of all, those nice looking Windows applications are really just protected mode DOS applications. Easily 99% of the world's Windows code runs on top of MS-DOS rather than on the NT operating system for the foreseeable future. Windows programmers will need a firm grasp of how DOS works and of how Windows interfaces with DOS.

Furthermore, plain vanilla DOS is hardly dead. DOS is still the proper tool for many tasks, witness the large number of DOS programs such as Microsoft's new DISKSPACE.EXE that's recently won a Computer Windows Critics' Choice award, or Windows programmer Jeff Prosise who has publicly argued that "DOS Must Die," nonetheless confesses to spending a major part of his workday at the DOS prompt. One of the major computer magazines we host edits a poll of readers that Windows is all important was quite recently predicting a final phase-in to Windows 3.1 using Xwrite. A prototype ancient DOS word processor MS-DOS may not win any awards, and DOS-based products may have a hard time attracting attention from the novelty crazed trade press, but the fact is that DOS remains a suitable platform for many tasks.

And yet, while the programmer we just mentioned spends most of his time at the C:\> prompt, it's important to note that it's a C:\> prompt within a Windows DOS box. The Windows DOS box is a very different beast from DOS itself. One of the goals of this second edition of *Undocumented DOS* is to help software developers understand the huge changes that DOS has undergone in the last few years. Yes, DOS remains tremendously important, but in many ways it's a different DOS.

What's New?

The first edition of *Undocumented DOS* appeared in October 1990, just after the release of Windows 3.0 (July 1990) and a bit before the release of MS-DOS 5.0 (June 1991). We have thoroughly updated this new edition to cover MS-DOS 5, MS-DOS 6, and Windows 3.1.

I've suggested a change in the emphasis of the DOS-Windows connection in the book *Undocumented DOS*. Rather than discussing the connection from the DOS side, where a connection is made at a low level, I've discussed the Windows side. A program such as Undocumented DOS's DOSMGR (the Windows protected-mode interface to MS-DOS) is a piece of Windows software that extends the MS-DOS operating environment to be part of Windows. Undocumented DOS's approach is task oriented: MS-DOS is a single-tasking operating system. With DOSMGR running, MS-DOS becomes a DOS-like component of a multitasking operating system.

DOSMGR—Windows' own device driver VxD (virtual device driver; see Chapter 1) knows about undocumented DOS functions and data structures and can therefore be interrogated by Windows programs. DOSMGR's author found the most important subset of undocumented DOS functions and data structures and wrote a Windows protected-mode DOS program that makes a host of undocumented DOS calls.

Windows 3 introduced a link to MS-DOS, a VxD. Other VxDs can be written to extend the capabilities of DOS. A VxD is a protected-mode DOS PC program that ISRs DOS functions. Instead of writing a TSR, you can write a VxD. ISRs are a nasty programmers' trick. VxDs are tricky, but they're a powerful tool. VxDs can be a programmers' playground. Windows 4 (code-named Chicago) will support the new version of DOS Windows.

So, to summarize the highlights of what's in this book's section on Windows:

- The DOS-Windows connection, including DOSMGR (Chapter 1) and VxDs (Chapter 3)
- Undocumented DOS from protected-mode Windows programs (Chapter 3)
- Interrupt reflection in MS-DOS 5 Windows (Chapter 4). Microsoft solved problems with undocumented DOS calls that the DOS 4 and earlier DOS Extenders depended on. DOS Extenders are a type of Windows software that makes undocumented DOS calls on behalf of Windows applications. Windows 3 solved most of these problems, but Chicago will require a new approach. This is covered in Chapter 4.
- Undocumented DOS programming (Chapter 5). Rather than a reference, this chapter is a tutorial on undocumented DOS calls. Its aim is to show how DOS programmers can use undocumented DOS calls to their advantage. Chapter 5 also includes a discussion of undocumented DOS vs. supported DOS and a complete examination of the documented INT 21h calls.
- Undocumented DOS Memory Control Blocks, Device Drivers, and Stacks (Chapter 8)
- Other undocumented DOS data structures, including the DOS Swappable Data Area, the DOS Drive Parameter Block, and the DOS File Table (Chapter 7)
- DOS Multiplex (INT 2Fh) programming (Chapter 5). For example, the INT 2Fh API for network redirectors is discussed, including a complete description of the XMS ram disk. We have also included a complete description of the network redirector (see Chapter 8).
- Loading device drivers (Chapter 7). How to load device drivers from the command line (see Chapter 7).
- The DOS Command Line (Chapter 7). The command line, TSRs loaded before Windows, and other useful tasks. How to manage the state of multiple DOS boxes (see Chapter 9).

- There is an [illegible] DOS: DR DOS [illegible] Novell DOS [illegible] DOS box [illegible] OS/2 [illegible] DOS [illegible] Windows NT [illegible] and even NetWare [illegible] NT [illegible] makes [illegible] DOS/NT 2F [illegible] different version of DOS (see Chapter 4).
- Ralf Brown [illegible] appendix [illegible] functions [illegible] DOS [illegible] the first edition [illegible] accompanying disk [illegible]
- [illegible] and of course we make [illegible] documentation for the old functions (see Chapter 1).

What Versions of DOS?

Of course, this edition covers MS-DOS 5.0 and 6.0 [illegible] MS-DOS 6.2 and as much [illegible] for example, Chapter 8 discusses long filenames).

As already noted, Chapter 4 [illegible] DOS, including DR DOS 6 and Novell DOS 7 [illegible] DOS box [illegible] OS/2 [illegible] DOS 2.x [illegible] and the DOS box in Windows NT.

[illegible] OEM [illegible] DOS [illegible] OEM [illegible] Geoff Chappell touches on OEM [illegible] MS-DOS [illegible] Microsoft's OEM [illegible] OAK [illegible] OEMs [illegible] DOS (see Chapter 6).

Is Any of This Useful?

[illegible] DOS [illegible] *Undocumented DOS* going to help you in your job?

[illegible] DOS [illegible] DOS [illegible] example [illegible] PSP [illegible] SFT (see Chapter 8), will be a better programmer.

[illegible] dependent details makes [illegible] However [illegible] Brad Pirnas [illegible] *The Mythical Man-Month: Essays on Software Engineering* (Addison-Wesley, 1975):

> [illegible]
> for disaster.

Lesson 1: "Information hiding" works only when all interfaces are completely and precisely defined. But this is almost impossible due to the absence of complete and precise interface definitions. Your best source is to learn as much about the system as you possibly can.

Secondly, surprising and unfortunately, how often DOS programmers actually do end up needing to use some undocumented feature. Four years ago, I got involved in the first edition of this book because I had an particular interest in undocumented interfaces or any sort of legacy. Microsoft's documentation department, but because in my job at Lotus I had run into situations where undocumented DOS was the only solution to a problem and the problem had to be solved because customers were demanding it.

Lotus has several excellent high-end CD-ROM products, including CD Corporate, CD Investment, CD M&A, mergers and acquisitions, and so on. These products require the Microsoft CD-ROM extensions, MSCDEX. Our customers would load MSCDEX, which takes up a lot of memory, solely in order to run our products as far as they were concerned. MSCDEX was part of our product's infrastructure, but not surprisingly, given how it works, not DOS. MSCDEX does not have a deinstall option. Customers really hated rebooting. We had to get rid of MSCDEX after running our products. I first attempted to deinstall MSCDEX by using Ken Kaminsky's excellent MARK and RELEASE utilities, but this didn't work because MSCDEX allocates discontiguous blocks, which MARK/RELEASE doesn't deal very well with. Our customers wanted a NOMSCDEX utility. It turned out that the only way to write NOMSCDEX was to manipulate the DOS Current Directory Structure. As you can guess, this structure is undocumented, and so is the DOS function that lets you access it (see DOS INVARS in Chapter 8).

Our version of NOMSCDEX predates 3.0's DOS. I'm not quite sure how NOMSCDEX, which only tweaked MSCDEX's changes to the CDS, could have ever worked. In any case, it did work, and customers were happy with it. A more robust NOMSCDEX would have involved even more use of undocumented DOS.

Soon after it became clear that our CD Networker product, a CD-ROM network server, would need to use Microsoft's network redirector interface. Trying to get this from Microsoft proved impossible. At this point, David Maxey and I realized that if Lotus couldn't get this information from Microsoft probably no one else could either, and it would be useful to do an entire book on the subject of undocumented DOS. That the book turned out to be quite popular among PC programmers shows that indeed this material is useful. There are even a few employees at Microsoft who "frightening thought" seem to rely on this book.

So, as for this material is not for the faint of heart. However, *before incorporating an undocumented DOS call into a commercial product, double-check and triple-check that there is no documented way to do the same thing.* There will be a few cases where undocumented is the only way to go, but in the vast majority of cases, using undocumented DOS will be a shortsighted decision. Even if the undocumented feature is used in a way that is completely conventional and totally well behaved, it is better to use a documented function since Microsoft makes no guarantees that undocumented DOS will work in future versions of DOS. Equally important, such practices rely on undocumented DOS the easier it is for Microsoft to produce future versions of DOS. Not to belabor the same thing also makes it easier for computers other than Microsoft to produce DOS-compatibles. This topic is addressed in greater depth in Chapter 1. In any case, assuming that undocumented way to accomplish some goal and then figuring out a documented way will also make you a better programmer.

What's With All the Legal Mumbo Jumbo?

The reader expecting a straightforward technical book may be wondering why Chapters 1 and 4 contain lengthy discussion of U.S. antitrust law and why Chapter 6 has a whole section on the law surrounding reverse engineering. What the heck is this doing in a book for programmers?

For better or for worse, you can't know software so narrowly anymore. It's not ethical. In a book on undocumented programming interfaces, every new avail that we have to stop staring at code and ask why a given interface is undocumented and ask whether Microsoft might derive some legal benefit from this lack of documentation. We then have to ask the bigger questions: Is there an "unfair" in this arrangement, given Microsoft's position both as the supplier of a vital block resource (the operating system) and as a key competitor with other applications vendors that use that resource? These are not rhetorical questions. I sure wish I knew the answers to them.

These seemingly non-technical issues are particularly relevant because an advance copy of some of the material in this book—early drafts of Chapters 1 and 4—were used in the U.S. Federal Trade Commission's (FTC) during its recent investigation into Microsoft. The FTC terminated its investigation with the commission's vote 2-2 over whether to issue an injunction against Microsoft. The U.S. Department of Justice (DOJ) has now taken up the Microsoft case.

At first, I viewed the FTC investigation with deep suspicion. The issue of undocumented interfaces seemed very narrow. While I felt Microsoft had tried to document interfaces that were vital to other software developers, I never really didn't seem to me particularly "unfair" as it were. Questions from the FTC staff about what Microsoft might have "done" to Windows to make it incompatible with other versions of DOS particularly Novell's DR DOS, struck me as ridiculous (for reasons I express in Chapter 1).

But after encountering the VARD code discussed in Chapter 1 and the Microsoft C compiler SetDPMI warnings code discussed in Chapter 4, I had to change my mind about a lot of this. Still, I haven't made up my mind about these issues as the case will have to be left to a somewhat confused and contradictory discussion in Chapter 1. What I find very disturbing, however, is Microsoft's competitive process is viewed as being super competitive. Because I do know that this is a important question for software developers who (wish) to become more dependent on Microsoft.

After Chapter 1 went to press and after an article on this subject appeared in *Dr. Dobb's Journal*, I was able to meet with Brad Silverberg, Microsoft's vice president of systems software, and Aaron Reynolds, a key developer at MS-DOS, Windows 386, and Windows Enhanced mode, and author of the VARD code discussed in Chapter 1. Microsoft's reply appears in the December 1993 issue of *Dr. Dobb's Journal*. Brad and Aaron did not persuade me that it's okay for Windows to be using DOS calls that Microsoft omits to document for other software vendors. Nor did they persuade me of the legitimacy of the VARD code's goal of warning users of non-Microsoft versions of DOS that running Windows on their system was "untested." What Brad and Aaron were most vehement about however, to reduce tech support costs for Windows. The fact that the method they chose would unnecessarily damage Novell's reputation with no real gain for Microsoft or its customers seems not to have occurred to them.

I hope the reader and the other authors will indulge some of my attempts to take this discussion beyond the narrow confines of how to make undocumented DOS calls. The places in the book where an assembly language disassembly listing appears directly at issue—discussion of some antitrust case like *Supreme Chicken Dandi* are my favorites. They also reflect my very mixed feelings about Microsoft's role in the software industry. Is Microsoft the software

equivalent of Edison's Menlo Park "invention factory" or is it just one prominent writer of programming books privately maintains "The Dark Side of the Force"? Neither, or both.

How Do I Get in Touch with the Authors?

Returning to more immediately practical issues, many readers of this book will want to know how to contact the authors with questions, corrections, suggestions, and criticism. Many of the improvements in this second edition are the direct result of feedback from many readers of the first edition.

For any overall comments on the book, and on Chapters 1, 4, 6, and 8, contact:

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I edit a monthly "Undocumented Corner" in *Dr. Dobb's Journal*, and am always looking for new topics and new writers. I am also starting a separate UNDOC newsletter. For details, see the README file on the accompanying disk. If you are interesting in learning more about the newsletter's price and frequency, which I have not yet decided upon, send your name and address via normal mail (not email) on this one, please, to:

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This is also the address to use if you want to contact the authors, but do not have email access. However, while I guarantee a response to email, I can't guarantee a response to "normal" (snail) mail.

For INT2FSPY, Phantom, Chapter 5, or the network redirector section of Chapter 8, contact:

David Maxey
CompuServe 70401,305
Internet 70401.305@compuserve.com

Please note that the version of Phantom on the accompanying disk has two known bugs, which unfortunately were not detected until the disk was already being produced. First, if DEVICE=HIMEM.SYS Phantom requires DOS=HIGH to run. Phantom under HIMEM without DOS=HIGH hangs the system. Second, Phantom allows only two directory levels, MID\DIR1\DIR2\DIR3 fails on a Phantom drive.

For DEVICE=ENVDISK, Chapter 7, and Chapter 10, contact:

Jim Kyle
CompuServe 70703,762
Internet 70703.762@compuserve.com

For the TSR library and Chapter 9, contact
Raymond J. Michels
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Internet 72300.2414@compuserve.com

For the Interrupt List, contact
Ralf Brown
Internet ralf@telerama.pgh.pa.us
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For updated versions of the Interrupt List, see the instructions in INTRIDX.INTERRUP.LST on the accompanying disk.

Did You Do This All By Yourselves?

Not exactly. The list of people who helped make this a better book is pretty long. The following people are not responsible for any of our errors or omissions, especially because we sometimes failed to implement their excellent suggestions, but they are responsible for much of what is good in the second edition.

Bob Archuleta	Carlson Backhold Anderson	David Andrews
Paul Andrews	Dwayne Bailey	Steve Baker
Stewart Berman	Doug Boling	Pat Bonneau
John Brennan	Chuck Brewer	Peter Burch
Ron Burk	Barbara Cass	Frank Cavallaro
David Chappell	Geoff Chappell	Peter Chew
Anton Chuzhoy	Norman D. Culver	F. Nicholas Cupery
John Desrosiers	drik.net	Ray Duncan
Grant Echols	Erick Engelke	Jon Erickson
John Fanz-Fanzmar	Klaus Farmerich	Tim Farley
Matthew Felton	Brad Finnegan	Karen Flesch
Eric Fogelin	George Fulk	Isabele Gavraud
Gils Gavraud	Steve Gibson	Drew Gislason
David R. Glandort	Barry Goldstein	John Hart
Rainer G. Haselier	Martin Heller	Robert Hummel
Tony Ingenoso	Ian Jack	Roger Jackson
Eduardo Jacob	Dave Jewell	Phil Jollans
Steven Jones	Mike Karas	Peter Kolber
Kati Kokkonen	Dmitriy Koudratiev	Gene Lamb
Jim Lerner	Bill Lewis	Charlie Little
Brian Livingston	Jay Lowe	Stephen Manes
David Markun	Mike Marrese	Philippe Mercier
Ted Mereda	Graham Murray	Mike O'Connor
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Hans Salvisberg	Arnt Schapers	Mitchell Schoenbrun
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Glen Slick	Richard Smith	Kyle Sparks
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Al Stevens	Andrew Tanenbaum	Stuart Taylor
Ray Valdes	Frank van Gilluwe	Terrence Vaughn
Rod in Walker	Jerry Watkins	Martin Westermeier
Arlo Wightman	Ben Williams	Bob Williamson
Dennis Williamson	Dan Winter	Clayton Wishoff
William T. Wommerberger	Dan B. Wright	Manfred Young
Richard Zigler	Kelly Zytaruk	

I am sure that I must have left someone's name off this list. If so, I am sorry. There are also several employees of Microsoft whose help we would like to acknowledge by name, but can't because the company wants to make sure that you understand that Microsoft in no way endorses this book or in any way helped with its contents. Thanks, guys!

While everyone I've just named has helped make this a better book, a few helped out to such an extent that they deserve special thanks.

Scott Chapp[illegible]	John "Dr. Dos" Fanning	Tim Farley
Gene Landy	Bill Lewis	David Markam
Larry Seltzer	John Spinks	

I hope to buy each of you several beers!

This book never would have happened without our literary agent, Claudette Moore, who is a pro's pro at taking things happen. Four years ago, when I was thinking about doing a book on the then-brand-new DOS Windows and OS/2, Claudette made the only two observations that I should start out with a book called *Undocumented DOS* and that separate books on other operating environments could be written at a later time. Thanks, Claudette! Thanks, too, to John Paul Moore for giving this project his blessing.

At Bench Marks Productions, Andrew "Spike" Williams has orchestrated the transformation of this book from a rough collection of ASCII files into the attractive pages you see now. And he did it with more than usual stress during this entire project. Spike was assisted by Jennifer Nolde and in the early stages by Chris Williams. Chris arranged a special week-long undocumented retreat to the Clipper Ship Inn in Scituate, Massachusetts, where large chunks of Chapters 1 and 3 were written.

Our copy editor, Meredith Raland, did a wonderful job transforming our technobabble-filled maps into reasonable English. She is responsible for any improvement in readability which will be noticed by you as you see what this was like in the first edition. Clearly, she did not see that last sentence.

A million thanks to Xavier Cazin for his work on the French edition, *Le couteau du DOS*.

At Addison-Wesley, special thanks to Phil Sutherland, Claire Horne, Lisa Roth, and Doris Ruderman. Mrs.

Thanks to my wife, Amanda Calabrese, and my son, Matthew Jacob Schulman, for putting up with me the past few months.

Andrew Schulman
Cambridge, MA

CHAPTER 1

Undocumented DOS: The Madness Continues

by Andrew Schulman

We go right at least as far back as 120K of memory inside COMMAND.COM for version 1.00 of MS-DOS as one of the smallest operating systems ever written. Not coincidentally, it's also the world's most widely used operating system. Although DOS 1.00 was pretty much a toy, lacking even DOS's lack of features but not its *bugs* that accounts in large part for its spectacular success. One estimate puts the number of personal computers that have been sold capable of running applications for MS-DOS at more than 20,000,000. Estimates of the installed base of DOS systems ranges from 50 million to 100 million. Some skeptics of these estimates suggest marketing hyperbole is involved, and call it "only" 35 million. Let's just make sure we're talking about a big operating system. It is worth noting that, except for the few copies shipped on IBM machines, the Microsoft Corporation makes perhaps an average of $25 for each copy of DOS sold. Gates's estimated net worth in 1989 is over $1 billion. Most of it comes from MS-DOS. Reading your novel MS-DOS will not NOT make you rich. What a sweet business!

On each of these systems, over the years, MS-DOS provides the same unfriendly and command-line-oriented user interface. A small group of power programmers has learned how to use undocumented DOS system calls and services (such as INT 21h functions 5Dh, 32h, 37h, 52h, 63h, and 64h) to make DOS respond to simple commands (such as DIR, TYPE, COPY, DEL, and even undelete these days). With undocumented DOS calls, it is possible to make DOS execute programs on disk files without the need to execute terminate-and-stay-resident (TSR) programs, to trap the Ctrl-Break interrupt, and to bypass DOS altogether and write directly to the hardware. The MS-DOS programmer's toolkit consists of several software interrupts, the most important of which is INT 21h.

Just as MS-DOS itself is not well documented, so too the documentation on how to program DOS is poor. Of the six books on DOS programming that I have on my shelf, I DOS Programmer's Reference by Terry Dettmann stands out. Dettmann's *Undocumented MS-DOS Programmer's Reference* is the most DOS information available. Let's see, what else is on my shelf? A modest-sized bookstore might carry all of seven different books on how to program MS-DOS. Not 21h calls. Not undocumented MS-DOS programming. Not even how to write ready-to-run .COM files. Just basic operating system stuff.

Most DOS programming books devote a few chapters to topics such as disk and file access, memory allocation, and perhaps even hardware-dependent performance tweaks, and then launch into lengthy appendixes of the INT 21h calls. These books usually tell you that DOS 2.0 introduced hierarchical directories, proceed to list the 2.0 calls, then forget all about DOS 2.0 functions. Character Output and Input are usually surprisingly poorly covered.

Clearly, MS-DOS is a very underdeveloped world, where numerous books that are readily available can hardly spell out a few basic concepts. MS-DOS is very small compared to many of the computer operating systems that it is possible to grasp. DOS programming is correct. In contrast to the unfathomed depths of most operating systems, such as UNIX, MS-DOS is an apparently small, static world in which everything there is to know already is known.

Well, not quite.

Open the Microsoft official *MS DOS Programmer's Reference* either the DOS 5.0 version from 1991 or the DOS 6 version from 1993 and you will find many strange gaps in the INT 21h function descriptions. For example, there are entries for function 51h "Get PSP Address" and function 54h "Get Verify State" with nothing at all said about numbers 52h and 53h in between. Other quasi-official references such as Ralf Brown's *Interrupt List* simply list the missing functions as "Reserved." Nonetheless, functions 52h and 53h are two named slots that Microsoft reserves for possible future use. Or perhaps some obsolete code that Microsoft no longer uses? Maybe something useful only to DOS itself?

Not exactly. If you turn to the appendix of this book you will find the following entries:

```
INT 21h function 52h    DOS 2+ -- Get SysVars (first of Lists)
INT 21h function 53h    DOS 2+ - Translate BIOS Parameter Block
```

Not only will you find functions 52h and 53h because, until recently, these too were undocumented.

One of these functions, INT 21h AH=52h, returns a pointer to the SysVars internal data structure in the DOS data segment. Practically every DOS utility in existence, whether written by Microsoft or by one of the many third-party DOS vendors such as Central Point Software, Quarterdeck, Stac Electronics, and Symantec uses function 52h and SysVars, also known as the List of Lists. Yet the function remains undocumented. Microsoft uses it, the major third-party software vendors use it, yet Microsoft has never even acknowledged its existence. This is more than just a case of the monopolization of a vital resource. We'll try to answer this question in the course of this chapter.

This is just one of many critical holes in the programmer's interface to MS DOS. There's a similar gap between functions 54h and 56h. This gap includes a crucial bit of functionality: function 55h "Create PSP." When DOS or Windows starts a program, it uses this function. Many third-party extensions to DOS, such as Phar Lap's 386|DOS Extender and NT LAN Manager's Windows for Workgroups WfW, Microsoft removed NT LAN Manager from MS DOS 6.0 at the last minute, use function 55h too.

Another notable aspect of DOS is function 5Dh. The *MS DOS Programmer's Reference* describes function 5D0Ah, which raises the inevitable question of whether there are other functions such as 5D00h, 5D01h, and so on. Not surprisingly, there are. In contrast to what the Microsoft official reference indicates, function 5Dh consists of 12 subfunctions that handle an assortment of tasks, including DOS calls over a network, Server Function Call, and support for DOS redirectors. Get Swappable Data Area, in fact, the one 5Dh function that Microsoft does document, has certain aspects that don't make much sense unless you know about the other ones.

Besides INT 21h, there are other DOS software interrupts, such as INT 2Fh, which contain entire undocumented subsystems. The most important of these is the Network Redirector INT 2Fh functions. Even those few who are privy to many non-programmer DOS networking software, yet Microsoft has never documented this function's programming interface, despite years of repeated requests from developers.

These undocumented functions are merely the most apparent portion of undocumented DOS. The real secrets are contained in DOS's data structures: the DOS internal variable table, SysVars, the System File Table, the Current Directory Structure, CDS, and numerous other structures that this book describes in detail.

Although MS DOS 6 has only 46 pieces of code, it is nonetheless far from being a self-enclosed, static creature like a mythical equation whose graph is infinitely complex. This small piece of code called DOS contains many unexplored areas. Unexplained, at least, by Microsoft.

"Cruel Coding" and Tying Arrangements

As a concrete example of how undocumented DOS is used in the real world, consider Microsoft's tremendously successful Windows operating environment, which runs on top of MS DOS. Later in this chapter, we will see that Windows (especially Enhanced mode) heavily depends on detailed knowledge of undocumented DOS functions and data structures, in particular INT 21 function 52h and SysVars. That Windows relies heavily on undocumented DOS is a fascinating avenue to explore in a book on undocumented DOS, but does have some bearing on antitrust practices.

The computer trade press has given a lot of attention to the question of whether Microsoft's position as the leading supplier of PC operating systems has given its applications an "unfair advantage" over *applications* by other vendors. Most of the articles surrounding the book *Undocumented Windows* had to do with the fact that Microsoft applications were able to use undocumented Windows functions. But the computer trade press may have been focused on the wrong issue. It is equally important to ask whether Microsoft's competing operating system, OS/2, gives it an unfair advantage in bringing out *new versions* and *upgrades* to *existing* products such as Windows and Excel, sooner.

The point we've made throughout this chapter that even though DOS is called "part of the operating system" and hence Microsoft's natural domain to do with as they see fit, undocumented DOS calls and DOS extensions are some of the most heavily competitive areas on the PC software marketplace. The existence of a large third party remarket for these undocumented extensions shows that a large group of consumers considers them separate from the operating system. The question is not competing for DOS market share, whether Microsoft is abusing its monopoly position as sole supplier of the world's predominant operating system, and whether it's illegal for Microsoft to profit from this position in the long run.

We can in part answer this question by looking at the relationship between Windows and MS DOS. The DOS/Windows combination raises important issues for Microsoft. On the one hand, Microsoft must avoid what is called a "tying arrangement" – one which ties one product, such as Windows, requires that a customer also buy another product, such as MS DOS, from the same company, and prevents customers in some way from buying a competitor's compatible product, such as Novell's DR DOS. Tying arrangements come under U.S. antitrust law, particularly section 3 of the Clayton Act, which explicitly prohibits as not competitive the lease or sale of commodities "on the condition, agreement or understanding that the lessee or purchaser thereof shall not use or deal in the goods, wares, merchandise, machinery, supplies or other commodities of a competitor or competitors of the lessor or seller, where the effect of such lease, sale or contract for such lease or sale or such condition, agreement or understanding may be to substantially lessen competition or tend to create a monopoly."

On the other hand, Microsoft can make a case to show that to properly run Windows, a user need to upgrade to whatever is the latest release of MS DOS. For example, the October 2nd, 1992 Microsoft "Reviewer's Guide" for DOS 6 states:

> *MS DOS must be a superior platform for Windows*
>
> Windows has become a standard. More than 6 million PCs are shipped with Windows, and the number is growing. The Windows application market is approaching the size of the MS DOS applications market. Given the widespread use of Windows, we plan to evolve MS DOS over time to:
>
> - Provide the same technologies that Windows needs to improve
> - Become more tightly integrated with Windows

Likewise, the README.WRI file included with Windows 3.1 states:

> *Running Windows version 3.1 on Operating System Other Than MS DOS*
>
> Microsoft Windows and MS DOS work together as an integrated system. They were designed together and extensively tested together on a wide variety of computers and hardware configurations. Running Windows version 3.1 on an operating system other than MS DOS could cause unexpected results or poor performance.

The point here is that the pieces of this "integrated system" are currently sold separately; this [illegible] Microsoft's forthcoming "Chicago" operating system. Of course, there's nothing wrong [illegible] separately, as are cars and tires, toasters and bread, and lamps [illegible] Kodak designed cameras that could only work properly with Kodak film [illegible] processed at Kodak processing centers. What if Kodak's camera division [illegible] technical informa[illegible] film and processors [illegible] whether this arrangement had a legit[illegible] existed for the sole purpose of excluding competition [illegible] such questions is no easy matter, a major reason why "vertical [illegible] dollars.

Has Microsoft created [illegible] between Windows and MS-DOS for the sole purpose of [illegible] this question several times in the course of this chapter. But let's first establish what ties exist.

[illegible] Windows makes extensive use of [illegible] DOS [illegible] and data structures, including INT 2Fh function 52h and SysVars.

[illegible] MS-DOS [illegible] Windows [illegible] there is a large and important [illegible] INT 2Fh interface the MS-DOS 5.0 and 6.0 [illegible] communicate with a key compo[illegible] Windows [illegible] DOSMGR [illegible] DOSMGR expects any DOS version 5.0 or higher to support the [illegible] which provides DOSMGR with information about DOS internals. [illegible] DOS [illegible] including DR DOS [illegible] DOS 3.31 [illegible] As this book was [illegible] Novell DOS 7.0 [illegible] DOS version number of 6.0 rather than [illegible] Novell [illegible] the undocumented DOSMGR interface.

[illegible] Windows [illegible] DOS. When Windows starts up, [illegible] some parts of DOS, when [illegible] a DOS 5.0 or 6.0 [illegible] *MS-DOS Programmer's Reference* [illegible] internal values at specific [illegible]

[illegible] MS-DOS [illegible] Windows. For example, the WIN386.386 file that [illegible] DOS [illegible] the code found in the V86MMGR component [illegible] Windows 3.0 [illegible] Microsoft's EMM386.EXE also patches two routines in V86MMGR.

What [illegible] MS-DOS and Windows are sold as separate products, they are [illegible] what happens to a non-[illegible] DOS [illegible] knowledge of undocumented DOS [illegible] MS-DOS [illegible] Windows [illegible] when Windows is [illegible] is running.

[illegible] MS-DOS a better platform for Windows. But this process [illegible] Microsoft [illegible] DR DOS [illegible] Microsoft competitors to [illegible] a problem, however, if Microsoft [illegible] MS-DOS. One obvious example would be putting [illegible] DR DOS.

[illegible] document functionality in DOS, which [illegible] MS-DOS [illegible] 52h, for example, then fail [illegible] Windows has legitimate [illegible] DOS [illegible] Microsoft's persistent failure to docu[illegible] Windows and MS-DOS are separate products for [illegible] Quarterdeck's Desqview and Novell's DR DOS.

Windows and DR DOS

During the aborted three year U S Federal Trade Commission FTC investigation into Microsoft now taken up by the U S Justice Department attorneys from the FTC were carefully looking at the relationship between MS DOS and Windows For example, *PC Week* November 30, 1992, reporting on the FTC investigation noted that

> Another area of scrutiny is whether Microsoft modified Windows to prevent Novell's DR DOS operating system from running with the graphical environment DR DOS required updates to work with both Windows 3 0 and 3 1

Certainly there is a history of incompatibilities between Windows and DR DOS But it is vital to filter out which of these incompatibilities are *not* Microsoft's fault There is a vague widespread notion that every incompatibility between Windows and DR DOS somehow reflects an attempt by Microsoft to sabotage its competitors The following letter to the editor of *PC Week* on September 15, 1992 is a good expression of this idea

> In response to Microsoft's cruel coding Windows 3 1 and DR DOS 6 0 are incompatible A rude message about the MS DOS extender popped up whenever I typed "win" at the prompt so DR DOS Technical Support faxed update disks to me from Digital Research and solved all my problems

While it sums up what "evil coding" means exactly the general idea is evidently that Microsoft introduces code into MS DOS and/or Windows for the sole purpose of hassling its competitors especially Novell As we will see this is not such a crazy idea But it does not follow that every incompatibility between Windows and DR DOS can be traced back to Microsoft

In this particular case Microsoft is not at fault The actual message that appears is "Standard Mode Fault in MS DOS Extender" This message comes from the Windows component DOSX EXE when you are trying to run Windows 3 1 Standard mode on DR DOS 6 0 It does not occur in Windows 3 1 Enhanced mode Dr Dobb's Journal contains a discussion of one of the rules of protected mode programming which indicates a bug in a program Indeed I hear from one of the DR DOS developers recently that in fact this one was DR DOS's problem

> On the subject of Windows interaction with DOS DR DOS 6 0 did not function correctly with Windows 3 1 however this was not a result of any intentional calls made by Windows The problem was caused by a incompatibility in the EXEC handler we called the "NEC" interrupt task hang It occurred during the EXEC call as it attempted to run some old NEC processors Windows DOS Extender ran in a DOS compatible mode and was trapped switching to protected mode and hung

> Windows 3 0 and 3 1 do make a number of undocumented calls to DOS if the version of DOS is 5 0 or higher We are sure prior to Novell DOS 7 0 preceding to be version COMPAQ 5 3 1 so Windows does not run these calls Under DOS 3 31 Windows is not as chatty as it is with networks so it does not cause any problems

So much for cruel coding Yet the FTC's Bureau of Competition took the possibility of Microsoft "cruel coding" very seriously for one of its attorneys asked in specifically about what Microsoft might have "put into" Windows to make it deliberately incompatible with DR DOS

At first this idea sounds completely ridiculous and is reminiscent of the old oft repeated but never proved dreck that MS DOS 2 0 contained code to deliberately break Lotus 1 2 3 According to mythology Microsoft's slogan was "1DOS and 1 do it all 1 of us don't run 2" see for example, Charles Bergquson and Charles Morris *Computer Wars* p 66 No one has ever shown that DOS 2 0 in fact contained such code or even explained what it would look like Perhaps

```
if (exe_file == "123.EXE") then
   halt_and_catch_fire();
```

Microsoft's practices (whether good or bad) usually exactly the opposite to ensure that popular applications run well under new releases of its operating systems, no matter what. The undocumented Windows/286 Application Load Segment function (see *Undocumented Windows*, Chapter 5) is a perfect example of the astute kludges Microsoft goes to in order to support popular applications (even from its competitors). Another example is the way SETVER reports itself to DOS 5 when competing for the services of application programs, hoping that DOS 5 will then behave in an incorrect manner. I hadn't consider the way MS-DOS 5 contains patches and workarounds for specific programs, including the Rational Systems DOS extender incorporated in Lotus 1-2-3.

Even though Windows and MS-DOS are rightly considered the two extremes in 386 enhanced mode operation, in fact, for example, while Windows can run multiple DOS boxes, there is only a single copy of DOS in RAM. What's the first surprise? To hear that DOS behaves differently when Windows is present? Indeed, it is important to realize that the DOS does by existing documented functions. When Windows starts up, it issues an INT 2Fh call with AX=1605h; when Windows exits, it issues an INT 2Fh call with AX=1606h. MS-DOS 5.0 and 6.0 hook these calls to maintain some enhanced operation. The INT 2F/AX=1605h documentation, as well as Microsoft does not document the way that MS-DOS 5.0 or 6.0 respond to these Windows calls. It does document the calls themselves in the Windows Device Driver Kit (DDK). The Windows DDK is a wonderfully obscure place to discover undocumented portions of DOS programmers' use. DOS programmers in the 1990s: everyone else's code is a potential Windows DDK. We're going to have to get used to looking on the Windows DDK. Even DOSPrint, a utility for Windows (but Windows will not generate one program!)

However, I'm troubled by Microsoft for doing exactly what their advertising says they do, which makes MS-DOS a better platform for Windows. One of the accusations against Microsoft sounds like a complaint from the second-tier software companies such as Novell, Lotus, WordPerfect, and Borland. One of these complaints about Microsoft is terrible the way some, Americans have begun to use the word, is called an unfair competitive practice.

Now, it's not illegal because of the undocumented calls created by the Windows Enhanced mode DOSMGR.386 and WINSPOOL.386 that MS-DOS 5.0 and 6.0 DOS emulators such as DR DOS 6.0 behave poorly in Windows Enhanced mode. Rather, it must pretend to be an older version of DOS such as DOS 3.31. Even though Microsoft has encrypted and copyrighted the interface as Novell DOS 7 does, there is nothing illegal about this. (I would recommend, in particular, the discussion in this chapter.) Microsoft doesn't have some of its products (such as MS-DOS 6) secretly trade "engineering" with another company (in particular, Windows 3.1). Even if a company has problems, say, it has trouble with undocumented interfaces, it cannot call on Microsoft to change Windows just because DR DOS 6.0 (albeit not DR DOS 5.0 or earlier) or Novell DOS 7.31. So what's behind these accusations about Microsoft engineering Windows not to run on DR DOS? We'll see in a moment.

Systems Rivalry and Smoking Guns Novell contends that Microsoft makes sole default use of undocumented calls. Of course, as DR DOS users discovered, there is no separate "Chinese Wall" inside Windows, as discussed in Chapter 5. But isn't this the nature of competition? A company should be praised for its product innovations, so long as these are really innovations and not simply "secret handshakes" with another "conspiracy," so to speak, its competitors.

However, in the U.S. there is some fascinating legal literature surrounding the issue of "predatory practices." Many of the issues surrounding Microsoft's travails with the U.S. Federal Trade Commission have been dealt with before in cases involving computer companies. Lotus and IBM, when it came to compatibles, form a fairly well established part of antitrust law, going back to the "tying arrangements" "non-price predation" and the "first mover advantage" of today's "product innovation."

What Microsoft wants to make MS-DOS a better platform for Windows, creating an *artificial* tie between Windows and MS-DOS for its sole purpose of existing. Now, would constitute predation?

The two crucial words here are "sole" and "artificial." Suits by Microsoft should be allowed to improve Windows even if it wasn't at all illustrative part DR DOS. This is a aggressive part the competitive process and nothing about "predatory innovation" has rights been created in the courts. For example many manufacturers of so-called plug-compatibles tried in 1970s to have the courts characterize IBM's System 360 as "predatory innovation." The courts rejected these claims along with eventually all of *U.S. v. IBM* 1969 82 thereby effectively requiring private to prove that the defendant's design had no redeeming virtue for consumers." Stephen F. Ross *Principles of Antitrust Law* 1993. In the sole "consumer" is assumed to be users.

A fascinating article on this subject is "Predatory Systems Rivalry: A Reply" by James Ordover Aaron Sykes, and Robert Wright *Antitrust Law Review* June 1983 who describe "systems rivalry" as follows:

> Suppose that company A manufactures a product system with two components A1 and A2 each sold separately. Company A has monopoly power over A1 but company B competes in the market for the second component with its compatible device, B2. Thus consumers normally can use a product system composed of either A1 and A2 or A1 and B2. Company A now introduces a new product system A1 and A2 which serves roughly the same function for consumers as the old product system. Component B2 however is incompatible with A1. Furthermore company A discontinues the sale of A1 or else reprices A1 substantial higher than before. As a consequence consumers switch to the new product system and company B is driven from the market by the company new two.
>
> When if ever should the antitrust laws sanction company A for driving B out of the market?

There's a clear comparison here to Windows 3.1 MS-DOS 5.x and DR DOS 6.0. The scenario which has nothing to do with operating system software underscores the fact that there's really little new in the questions surrounding Microsoft.

Normally a dominant player in the market is allowed competitors a fair share. There's a gray area of competition and should be protected. Society can tell when this ceases to be "fair" competition and becomes predation. "Predatory Systems Rivalry" provides a good test:

> the plaintiff must bear the burden of proof on this issue. It must establish the dominance of R&D expenses by a preponderance of the evidence. The plaintiff would most likely need a "smoking gun" a document or oral admission that vividly reveals the innovator's culpable state of mind with respect to the R&D decision. Alternatively the plaintiff could prevail if the innovation in question had no redeeming virtues but we cannot conceive that it would be true that a product has but an anticompetitive purpose.

This is what the question of was DOS Windows connection seems down to. Has Microsoft done anything to Windows and/or MS-DOS for an anticompetitive purpose? Let's look at the closest thing we have to a "smoking gun."

The Windows AARD Detection Code

If you were one of the 15,000 Windows 3.1 beta testers and if you happened to be using DR DOS rather than MS-DOS you probably encountered the following seemingly innocuous yet odd error message generated by WINCOM:

```
Non-Fatal error detected. error #2726
Please contact Windows 3.1 beta support
Press ENTER to exit or C to continue
```

As we'll see this message is a visible manifestation of a piece of code in Windows whose implementation is technically slippery and evasive and which extensively uses tables mentioned DOS. A careful

...DR DOS 6.0 program, this code doesn't appear to have a benign goal. Rather, its apparent purpose is to ... undocumented, arbitrary technical obstacles for "untested" DOS workalikes, DR DOS in particular.

The first version that appeared with a DR release labeled "final beta release" build 61 ... dated December 20, 1991, the "Christmas beta." ... build with "pre-release build 3.10.0068" January 21, 1992. ... Startup messages with different error numbers are produced in builds 61 and 68 by SETUP.EXE, ... by the versions of HIMEM.SYS, SMARTDRV.EXE, and MSD.EXE (Microsoft Diagnostics) ... packaged with Windows. Although the exact version data that ... the program can customize messages, WIN.COM's default behavior is to terminate the program rather than continue.

The ... message first appeared in build 61, a late-stage beta, ... disappeared in the final retail release of Windows 3.1. However, the code that generates the message is present in the retail release, ... executed every time you run Windows 3.1. In fact, we will see that one reason ... Windows uses undocumented DOS function 32h is to mislead the code that during the beta generated this error message on DR DOS.

... learn that the messages which appeared when running on DR DOS, including a beta of ... by version, now named Novell DOS 7.0, did not appear when running on MS-DOS or PC-DOS. ... the next question: what causes the error message?

... two obvious suspects are Microsoft, who would jump to the immediate conclusion that this code must be signs of undocumented goodies inside Windows. Why else, they might say, would the ... appear on DR DOS but not on MS-DOS? But until you know for sure exactly how the ... message is generated, it would be far more reasonable to assume that it's the manifestation ... of Novell or one of Novell's DR DOS ... It wouldn't be the first time a company's ... had ... Microsoft's ... product.

... to see why the error message appears in DR DOS but not in MS-DOS requires examining the ... code. WIN.COM first produces the message. However, this section said that some Unlike ... programs, ... code is found in ... versions of the Microsoft C compiler (see "Microsoft C Versions and Switches" ... chapter 4). ... disabled code in WIN.COM is XOR-encrypted self-modifying, ... disassembly.

The code ... attempts to step through it in a debugger. For example, figure 1.1 ... code fragment ... which WIN.COM points the INT 1 single-step interrupt at invalid code ... Only then ... WIN.COM does the same thing with INT 3 nonmaskable interrupts and ... software breakpoints. ... was produced by running Microsoft's DEBUG on the Windows ... version of WIN.COM. As noted earlier, the same code is found in four other programs that ship with Windows.

Figure 1.1: The AARD Code in WIN.COM Attempts to Disable a Debugger

```
C:\DOS\AARD>debug win31\win.com
-u 3d0a
;;  Note that setting DS to 0, going to fiddle with intr vect table
7055:3D0A 33C0          XOR     AX,AX           ; AX = 0
7055:3D0C 8ED8          MOV     DS,AX           ; DS = 0

;;;
7055:3D0E A10400        MOV     AX,[0004]       , get INT 1 offset
7055:3D11 2EA33D34      MOV     CS:[343D],AX    , save away
7055:3D15 A10600        MOV     AX,[0006]       , get INT 1 segment
7055:3D18 2EA33F34      MOV     CS:[343F],AX    , save away
7055:3D1C BBAC3F        MOV     BX,3FAC         , set new INT handler ofs
7055:3D1F 891E0400      MOV     [0004],BX
7055:3D23 8C0E0600      MOV     [0006],CS       , set new INT handler seg

-u 3fac
6B30:3FAC FFFF          ???? DI                 ; the new INT handler
6B30:3FAE CF            IRET                    ;    is 'invalid code'
```

Yes WIN.COM contains this code which looks like something out of a teenage virus writer's nightmare. The code in Figure 1-1 would disable any attempt to set breakpoints in DEBUG. In Figure 1-1 we were still able to use DEBUG to examine this DEBUG-defeating code because rather than set breakpoints we used the DEBUG U (unassemble command. Unfortunately WIN.COM's reverse engineering of INT 3 (also used by modern debuggers such as Nu-Mega's Soft-ICE) what runs the debugger and debuggee in separate address spaces. In any case these attempts to throw pursuers off the track are in themselves quite revealing.

These attempts become far more effective later on when the code is actually *encrypted*. WIN.COM passes the encrypted code through an XOR filter before execution. Here is a large amount of what we can only call "obfuscated" code. You can see this for yourself by using DEBUG to unassemble the Windows 3.1 retail version of WIN.COM on the SYSTEM.WIN (Nov. dated March 10, 1992 which Windows 3.1 SP1 uses to load WIN.COM code. DEBUG's encrypted code starts at offset 3C12h and ends at 31ABh.

```
C:\WIN31>type aard.scr
u 3ce2 3fae
q
C:\WIN31>debug win.com < aard.scr > aard.lst
```

Turning the resulting AARD.LST back into something reasonable when you're done cause you many hours of grief.

For some reason, while most of the code is XOR encrypted, it continues as plain text. Microsoft copyright notices and the strings AARD and RSAA (perhaps the programmers' signature) fill as fucked spaces in the press-secret example. Words Goldman Rodeo. We the [illegible] Its Serious Mess. Microsoft's Mischief. *Level* August 1995 [illegible] was written [illegible] rather than Aaron Reynolds one of Microsoft's most highly [illegible] and well-respected programmers and a stalwart of both MS-DOS and Windows. Either way this block of code has become known as "the AARD code."

A Gauntlet of Tests Once [illegible] and released on the world [illegible] to see if anyone can crack the AARD code. Figure 1-2 shows a pseudocode summary of the (unassembled) code. In essence the AARD code, which comes as part of Windows, is meant solely as a test for MS-DOS users of undocumented DOS functions. It does not check for genuine MS-DOS or PC-DOS.

Figure 1-2: Pseudocode of the AARD Code in WIN.COM

```
move (and fixup) code from 2019h to 4E0h
call code at 4E0h
    call AARD code at 39B2h
        -- see below
    IF (AX doesn't match 2000h)
        AND IF (control byte is non-zero)   ;; added in retail
            THEN overwrite BYTE at 4E0h to a RET instruction
;...
IF (byte at 4E0h is a RET instruction)
    THEN issue non-fatal error message

AARD code at 39B2h
    point INT 1, 2, 3 and at invalid code to confuse debuggers
    call undocumented INT 21h AH 52h to get SysVars  ( list of lists )
    copy first 30h bytes of SysVars to stack
    copy first 4 bytes (DPB ptr) of copy of SysVars to stack
    IF DOS version >= 10.0 (i.e., OS/2)
        THEN don't set [bp+196h], so eventually OR AX, 2000h fails
    ELSE
        check fields in SysVars to ensure non-zero:
```

```
        SysVars[0] -- Disk Parameter Block (DPB)
        SysVars[4] -- System File Table (SFT)
        SysVars[8]   Clock device
        SysVars[12h] -- Buffers header
        Sysvars[16h] -- Current Directory Structure (CDS)
        Sysvars[0Ch] -- CON dev ce
        SysVars[22h] -- Device driver chain (NUL device next ptr)
    IF no Sysvars fields are zero (MS-DOS, or WIN.COM in DR DOS)
        THEN set [bp+196h] so that eventually OR AX, 2000h succeeds
    ELSE some are zero  e g , MIMER SYS in DR DOS)
        THEN don't set [bp+196h], so eventually OR AX, 2000h fails
    copy code
    jump to copied code
    copy and XOR code
    jump to copied and XORed code
    ;; the fo  owing crucial part was figured out by Geoff Chappell
    If a redirector is running (INT 2Fh AX=1100h)
        AND If defau t upper case map (INT 21h AH 38h) in DOS
              data segment (undocumented INT 2Fh AX=1203h)
    OR If no redirector
        AND If F rst System FCB header (SysVars[1Ah]) offset == 0
    THEN DOS is considered okay
    ELSE (e g , WIN COM, SMARTDRV EXE, etc  in DR DOS)
        THEN C ear part of [bp+196h] so eventually OR AX, 2000h fails
restore previous INT 1, 2, 3
jump back to saved return address
```

As you can see, lines 1–2 of the AARD code rules heavily on undocumented DOS functions and data structures. It uses undocumented INT 2F function 52h to get a pointer to the DOS internal SysVars structure, a pointer that is known by several names. SysVars contains pointers to other DOS internal data structures, such as the first disk parameter block (DPB), the first system file table (SFT), the CLOCK device, and the console device driver. The AARD code uses several of these pointers in SysVars in ensuring that it is operating under a real version of DOS.

To make sure that it is running under a DOS compatible version, the AARD code checks several DOS internal data structures. Because real MS-DOS does not support the undocumented functions in the AARD test, it passes the test with flying colors. We'll see what we will see about the DOS data structures when we look at the undocumented DOS data structures later in this chapter.

The AARD code is also designed to make sure that it is not running under a DOS emulator such as Windows NT's NTVDM.EXE. It turns out that DR DOS 6 and later versions implement undocumented INT 2F function 1203h differently from MS-DOS. Instead of returning a pointer to the DOS internal SysVars structure, DR DOS 6 and later versions return a pointer to a structure containing a pointer to the SysVars structure. Thus, the Windows 3.1 beta HIMEM.SYS fails when it tries to access the A20 handler address. Under DR-DOS 6.0 and 6.0 Network, the AARD code fails under Windows NT's NTVDM.EXE when the DOS version is set to 5.50 or greater (for example, DOS 5.0 5.0 1 masquerades as DOS 5.50). This is not an appropriate test, the most dedicated test however appears at the end of the AARD code and is graphically depicted in Figure 1.3.

Figure 1.3 The Crucial AARD Test for DOS Legitimacy

```
If a redirector is running (INT 2Fh AX=1100h)
    AND If default upper case map  INT 21h AH=38h) in DOS
          data segment  undocumented INT 2Fh AX=1203h)
OR If no red rector
    AND If F rst System FCB header (SysVars[1Ah]) offset == 0
THEN DOS is considered okay
```

As Geoff Chappell (author of the book *DOS Internals*) first checks to see whether a network redirector such as MSCDEX is running. In this case, AARD checks that DOS's undocumented case map is located in the DOS data segment, which is located by calling undocumented DOS INT 2Fh AX=1203h. If no redirector is running, AARD checks that the pointer to the first System File Control Block (FCB) is located on a paragraph boundary, that is, it

has a 0 offset. AARD gets the pointer to the first System FCB from offset FAh in the SysVars structure retrieved earlier using undocumented DOS function 52h. All versions of MS DOS pass this test, as does version of DR DOS does.

To test whether this interpretation of the encrypted and heavily obfuscated code is correct, listing 1-1 shows MSDETECT.C. This program performs the same tests as the original AARD code, but without the obfuscations and with more informative error messages. MSDETECT succeeds under all versions of MS DOS tested (2.x, 3.x, 4.x, plus DOS 3.31, MS DOS 5.0, MS DOS 6.0, and all flavors of several versions of DR DOS tested (DR DOS 5.0, DR DOS 6.0, Novell DOS 7, etc.). But it is running under DR DOS with redirector, MSDETECT displays the message "Actual first FCB not in DOS data segment!" Otherwise, it fails, as does DR DOS with the message "First System FCB not located on paragraph boundary!"

Listing 1-1: MSDETECT.C

```
/*
MSDETECT.C
Andrew Schulman, May 1993
From  Undocumented DOS , 2nd edition (Addison-Wesley, 1993)
See also Dr  Dobb's Journal, September 1993

A duplication of Microsoft's MS-DOS detection code from Windows 3.1
WIN.COM (WIN.CHP), SMARTDRV.EXE, HIMEM.SYS, SETUP.EXE, MSD.EXE

The original Microsoft code (with the initials 'AARD') is heavily XOR
encrypted and obfuscated.  Here the encryptions and obfuscations have
been removed.  The AARD code also attempts to disable debuggers by
pointing INT 1, 2, and 3 at invalid code (FFh:FFh), this also has
been avoided here.

The original AARD code non-fatal error message has been replaced
with more informative messages about the exact problem  (i.e.,
difference from MS-DOS).

Geoff Chappell deciphered the original code's tests (upper case map
segment, System FCB) in the case where the preliminary SysVars tests
fail.  Some of this material is discussed in Geoff's forthcoming book,
"DOS Internals" (Addison-Wesley, 1993).

Optional command-line switches  DOREDIR and  NOREDIR have been added
to aid testing both crucial tests whether or not a redirector is
actually installed.

Build program with Microsoft C:  cl msdetect.c
*/

#include <stdlib.h>
#include <stdio.h>
#include <string.h>
#include <dos.h>

typedef int BOOL;
typedef unsigned char BYTE;
typedef unsigned short WORD;
typedef unsigned long DWORD;
typedef void far *FP;

BYTE far *_dos_getsysvars(void);
FP _dos_getcasemap(void);
WORD _dos_getdataseg(void);
BOOL _dos_isredirector(void);

void fail(const char *s) { puts(s); exit(1); }

main(int argc, char *argv[])
{
    BYTE far *sysvars;
    int do_redir = 1;
```

```
    // this is just to make testing easier
    // can fake presence or absence of a network redirector
    // to exercise both tests
    if (argc > 1 && argv[1][0] == '-')
    {
        char *s = strupr(&argv[1][1]);
        if (strcmp(s, "DOREDIR") == 0)
            do_redir = 1;
        else if (strcmp(s, "NOREDIR") == 0)
            do_redir = 0;
        else
            fail("usage: msdetect [-doredir] [-noredir]");
    }
    if ((sysvars = _dos_getsysvars()) == 0)
        fail("INT 21h AH=5200h returns 0!");

    if (_osmajor >= 0x0a)
        fail("DOS version >= 10, this is OS/2 (or early NT beta?)");

    #define SYSVARS(ofs)            (*((FP far *) &sysvars[ofs]))
    #define SYSVARS_TEST(ofs, msg)  if (! SYSVARS(ofs)) fail(msg)

    SYSVARS_TEST(0,  "Disk Parameter Block (DPB) pointer is 0!"),
    SYSVARS_TEST(4,  "System File Table (SFT) pointer is 0!");
    SYSVARS_TEST(8,  "CLOCK$ device pointer is 0!"),
    SYSVARS_TEST(0x12,  "BUFFERS header pointer is 0!"),
    // next test fails in device driver init (HIMEM.SYS) under DR DOS 6.0
    SYSVARS_TEST(0x16,  "Current Directory Struct (CDS) ptr is 0!");
    SYSVARS_TEST(0x0C, "CON device pointer is 0!"),
    SYSVARS_TEST(0x22, "Device chain ptr (from NUL) is 0!"),

    if (!_dos_isredirector()) && (do_redir == -1))
        do_redir = 0;
    // the following tests fail under DR DOS 5 and 6
    // (and under beta of Novell DOS 7)
    if (do_redir)
    {
        FP casemap;
        puts("Doing redirector test");
        casemap = _dos_getcasemap();
        if (FP_SEG(casemap) != _dos_getdataseg())
            fail("Default case map isn't in DOS data segment!");
        printf("case map @ %Fp\n", casemap);
    }
    else
    {
        puts("Doing no-redirector test");
        if (FP_OFF(SYSVARS(0x1A)) != 0)
            fail("First System FCB not located on paragraph boundary!");
        printf("System FCB ptr @ %Fp -> %Fp\n", sysvars+0x1a, SYSVARS(0x1A));
    }

    // if get here, everything checks out
    puts("All tests check out  must be MS-DOS");
    return 0;
}

// undocumented function
BYTE far *_dos_getsysvars(void)
{
    // could initialize ES:BX to 0:0 but the MS code doesn't do this
    _asm mov ax, 5200h
    _asm int 21h
    _asm mov dx, es
```

```
    _asm mov ax, bx
    // ES:BX retval moved into DX:AX
}
// formerly undocumented function
BOOL _dos_isredirector(void)
{
    BYTE retval;
    _asm mov ax, 1100h
    _asm int 2fh
    _asm mov retval, al
    return (retval == 0xFF);
}
// undocumented function
WORD _dos_getdataseg(void)
{
     _asm push ds
    _asm mov ax, 1203h
    _asm int 2fh
    _asm mov ax, ds
    _asm pop ds
    // retval in AX
}
// documented function - get far pointer to default case map
FP _dos_getcasemap(void)
{
    BYTE country_info[34];
    FP fp = (FP) country_info;
    _asm push ds
    _asm mov ax, 5800h
    _asm lds dx, dword ptr fp
    _asm int 21h
    _asm pop ds
    return *((FP far *) &country_info[18]);
}
```

A Gratuitous Gatekeeper [illegible] DOS [illegible] case [illegible] which [illegible] DOS [illegible] which [illegible] anyway?

[illegible] and [illegible] DOS [illegible] last [illegible] DOS [illegible] relies [illegible] was [illegible] purpose [illegible] DOS [illegible] pinnately vague "error" message.

[illegible] perfect [illegible] DOS [illegible] specific [illegible] DOS [illegible] change [illegible]

points to Real mode. In real mode, a single memory location can be addressed by different pointers; there are many combinations of different segment and offset values that all resolve to the same physical address. In fact, there are 4,096 equivalent. Not surprisingly, Windows is affected by this change to these pointers. As shown in Figure 1-4, the only software that noticed was MSDETECT and the AARD code in WINCOM.

Figure 1-4: Making the AARD Code Fail

```
C:\UNDOC2\CHAP1>symdeb
Microsoft Symbolic Debug Utility
Windows Version 3.00
(C) Copyright Microsoft Corp 1984-1990
Processor is [80386]

;;; The first System FCB is stored in this configuration at 0116:0040,
;;; so denormalize the pointer at that location, changing it from
;;; 05E4:0000 to 05E0:0040. This points to the same exact location,
;;; but since the offset isn't zero the AARD test fails.

-dd 0116:0040 0040
0116:0040  05E4:0000
-ed 0116:0040 05E0:0040

;;; Now normalize the pointer for the default case map. I had to
;;; disassemble the code for INT 21h AH=38h to find where this is
;;; located. The pointer is stored here at 0116:12A8. Below, the
;;; pointer is changed from 0116:0CF5 to 01E5:0005. This points
;;; to the same exact location, but the segment isn't 0116 (DOS data
;;; segment) anymore, so the AARD test fails.

-dd 0116:12a8 12a8
0116:12A8  0116:0CF5
-ed 0116:12A8 01E5:0005
-q

C:\WINBOI>win
Non-fatal error detected: error #2726
Please contact Windows 3.1 beta support
Press ENTER to exit or C to continue

C:\UNDOC2\CHAP1>msdetect
Default case map isn't in DOS data segment!
```

These results are hardly surprising. Dave Jones' recent *Microsoft KnowledgeBase* article "Replace Case Mapping Function with Equivalent" (Version 1.00, Q49736, April 29, 1993) reminds us that it is perfectly legitimate and documented for a DOS program to hook INT 21h, AH=38h and replace the built-in case mapping function.

As has already been noted above and a few times, Windows relies heavily on undocumented DOS calls. This usually is a problem when new versions of DOS come out, but perhaps the AARD code is simply scanning the undocumented DOS structures looking for DOS patches to support the undocumented DOS calls upon which Windows relies. I don't think so, since the AARD code does test for the presence of internal DOS data structures whose existence several versions later Windows no longer relies on. *It is the AARD code stopped there* [illegible] *and the Windows code that does not.* However, DR DOS does not fail these tests in WINCOM. DR DOS has other undocumented System FCB case map tests in Figure 1-3. And Windows does not rely on that behavior at all.

In order to confirm exactly what MSDETECT and, presumably, the operating systems, it would be perfectly legitimate to look at the DOS data structures to see that they were the same as would be expected in a genuine MS-DOS. Or, if the AARD tests fail, to see those DOS internal data structures on which Windows actually relies that too would be legitimate. Though we still have to ask why Windows should rely on aspects of MS-DOS that Microsoft chooses to disclose to the rest of the software development community. However, the fact that WINCOM and other programs incorporating AARD code

[illegible] error message [illegible] rather than [illegible] need to know [illegible] information about the underlying DOS

The very [illegible] Windows [illegible] MS DOS [illegible] despite the detected "error" [illegible] error [illegible] Windows [illegible] it seems that the only "error" is that the user [illegible] Windows [illegible] DOS

Does Beta Code Really Matter? The non fatal error message appeared only in two widely distributed beta builds of Windows [illegible] Windows 3.1 [illegible] just dead history, right?

Not quite [illegible] Windows 3.1 [illegible] WIN.COM or WIN.CNF [illegible] the error message [illegible] AARD and RSAA [illegible] other words [illegible] AARD code [illegible] Windows. The AARD [illegible] Windows [illegible] SMARTDRV.EXE [illegible] HIMEM [illegible] MSD

[illegible] WIN.COM [illegible] MSDPMI [illegible] AARD [illegible] the AARD portion of Windows 3.1 [illegible] WIN.COM [illegible]

[illegible] WIN.COM [illegible] AARD [illegible] control [illegible] error message [illegible] currently 0 [illegible] WIN.COM [illegible] DR DOS [illegible] DR [illegible] DR DOS [illegible] MS DOS [illegible] WIN.COM triggers the printing of the message

Figure 1 5. Resurrecting the AARD Error Message in Windows 3.1 Retail

```
C \DRDOS6>debug w n com
DEBUG v1 40    Program Debugger
Copyright (c) 1985,1992 Digital Research Inc  All rights reserved
CPU type is [i486 in virtual 8086 mode]
-d 16d4 16d4
2271:1600           00
-e 16d4 1
 g
Non-Fatal error detected: error #2726
Please contact Windows 3.1 beta support
Press ENTER to exit or C to continue
Program terminated.
```

[illegible] message [illegible] appeared [illegible] beta [illegible] the retail version [illegible] Microsoft [illegible] programs [illegible] releases [illegible] 15,000 Windows 3.1 beta sites [illegible] customers [illegible] sites [illegible] *PC Week*, *InfoWorld* and *PC Magazine*. Many [illegible] beta versions [illegible] So it appears that Microsoft [illegible] Windows beta program as a way to leverage MS DOS against [illegible] as DR DOS

So What? A non-fatal error message in a beta version that's all. If you have an axe to grind with Microsoft, you may have expected some more nakedly robber-baronesque behavior. If this is the worst that can be found, perhaps things aren't so bad after all. Note, however, that at least one other "smoking gun" has appeared: the amazing warranty-related error message in QuickC and Microsoft C 6.0, discussed in Chapter 4. While it's difficult to second-guess the precise goal of the encrypted and obfuscated AARD code, its results are clear enough: Windows beta sites that used DR DOS rather than MS DOS would have been treated to nonsensical warnings. "Doctor, every time I do this I get a non-fatal warning." "Then stop doing it."

Speculating further, a considerable goal of the AARD code was to delay Novell's attempts to get a new version of DR DOS that is compatible with Windows 3.1. Recall that the AARD code was added to Windows toward the end of the beta test cycle. The scenario then was as follows: Novell notices the message and panics that its customers will get weird errors whenever they run Windows 3.1. Its logical next step will be to reverse-engineer WIN.COM in order to figure out why. However, the code has been so carefully written to obscure the precise test that is being conducted—and you thought those "Obfuscated C" contests served no practical purpose!

The effect of the AARD code is to create a new and highly artificial test of DOS compatibility. Such obfuscations and encryptions make it difficult for a competitor even to determine what is being tested. An indication that the AARD code's obfuscation was successful is the fact that a beta version of Novell's latest version of DR DOS fails the test, even though this version is otherwise far more compatible with MS DOS than previous versions.

Still, it's hard to believe that Microsoft would exert such efforts to clobber something with as little market share and as many problems as DR DOS. DR DOS's best place in the sun was during the brief era between MS DOS 4.0 and PC DOS 4.0 releases from IBM and as soon as MS DOS 5.0 came out, any reason to use DR DOS pretty much evaporated for retail customers, at least. But consider OEM purchasers who ensure that every PC DOS or MS DOS system they sell has a DR DOS or Novell DOS sticker on it. For every single non-IBM PC sold today, Microsoft receives a royalty—something like $25. (For the sake of Marks and Andrews, *Gates*, pp. 263–269, we've not included discussion of Microsoft's per-machine rather than per-copy OEM pricing of MS DOS. Microsoft's refusal to listen to Intel's experiences with AMD and Cyrix years ago is a threat, no matter how large its wonderful monopoly position.)

Microsoft's Response While Microsoft has provided no formal response to these accusations, Brad Silverberg, Microsoft's Personal Systems Software vice president in charge of Windows, was quoted in *Upside* (August 1993) as providing the following explanation for the AARD error message: "Windows is designed for MS DOS. If DR DOS is 100 percent compatible with MS DOS as they claim, then it would never show up."

The implication is that if DR DOS gets an error message from Windows that MS DOS doesn't get, then by definition it is Novell's fault and proof that DR DOS isn't 100% compatible, which it is. (For more on this story, see Chapter 4.) The problem with this argument is that, as seen in Listing 2.3, the AARD code's detection of DOS compatibility is 100 percent artificial. By Microsoft's definition of "MS DOS compatible," the only way for DR DOS to be identical with MS DOS and therefore in violation of copyright is to be "100 percent DOS compatible."

As for why Microsoft decided to include the code's output in the final shipping version of Windows 3.1, Silverberg told reporter Wendy Rohm, "It wasn't worth the hassle." Rohm: "The hassle of?" Silverberg: "Oh, people do not want to ask me questions like this." Laughs. (*Upside*, August 1993.)

Privately, a high-level manager at Microsoft was reportedly told us that there can't be any malicious intent in the AARD code because Microsoft is "agnostic" regarding DR DOS. This seems unlikely given the effort reported to write this tricky code. Its presence in five otherwise unrelated programs also points to fairly concerted effort. As it is unlikely that five such different programs are all maintained by the same person, in fact the programs probably fall under the domain of several different product managers or divisions. Finally, this same Microsoft official has argued that the AARD code represented

a legitimate effort by Microsoft to ensure compatibility and reduce technical support costs for Windows. The AARD code, in other words, is really a form of quality control to protect Windows' good will." The argument goes something like this:

- Windows is not just another DOS application but part of a "seamless" integrated system with MS-DOS. It is seen to be just another way of saying that Windows relies heavily on undocumented DOS internals.
- Microsoft has no guarantee that other vendors' versions of DOS support all the DOS functionality that Windows requires.
- Microsoft is not obligated to test Windows on those others vendors' versions of DOS.
- Therefore, Microsoft needed a way for Windows to test for the presence of some other untested version of DOS and to warn the user of a *potential* problem (or, at the discretion of Windows, refuse to run) if that version of DOS was untested and was not guaranteed to work.
- The test had to be encrypted and obfuscated in some way or otherwise the clone DOS vendor could easily circumvent the test by changing its DOS version number to whatever Windows was testing for, without bothering to make its DOS more compatible.

Note that this defense of the AARD code rests on Windows' use of undocumented DOS calls. According to the argument, the AARD code is not deliberately incompatible; that is, it serves a legitimate purpose for consumers, because Windows depends on nearly 100 undocumented DOS calls and structures that Microsoft has no guarantee that Windows will work on every other DOS. In other words, Windows rests on undocumented DOS calls, and the AARD code was an attempt to prop up this shaky foundation.

But in this case, why not test for the specific undocumented DOS functions on which Windows relies? Why test for features that Windows doesn't care about, for consistency's sake? Digital Research System DOS was a prime target. Microsoft has consistently claimed that it was not deliberately incompatible. The Windows test program was looking for versions of DR-DOS with because DR-DOS failed to pass the undocumented "get list of lists" test. This does not look like a form of quality control or the mere protection of Windows' goodwill.

Documentation vs. Tying If Microsoft needs to exert control over how Windows runs on top of competing operating systems, surely there must be other, more legitimate ways to do so. Microsoft is by tying Windows to MS-DOS via warning messages and encrypted code. If Windows relies on specific undocumented aspects of DOS, says Microsoft, it is *because* of the way Microsoft wrote Windows, not because of any underlying DOS limitation. Instead of the AARD code, Microsoft could have issued a specification describing the internal DOS calls and data structures that Windows requires. Then DR-DOS could have met those specifications, so would Compaq DOS, or Microsoft could produce a DOS of its own. MS-DOS has provided a documented equivalent for the undocumented DOS service to LOCK/UNLOCK FILE in Windows. The alternative to Microsoft's tying of Windows and MS-DOS, in other words, is *documentation*.

Interestingly, when a company says that one of its products must be used in some way, lawyers have long held that the company can instead produce specifications of permissible product standards. For example, in *Siegel Cooke & Kelton* (1971), a case Chicken Delight participated in, franchisees to purchase all their supplies and mixes directly from Chicken Delight. The court held that this was necessary, as "effective control could be achieved by specifications for cooking procedures, machinery and the type and specifications." Similarly, Microsoft could document the "secret" calls and specs as it were Windows expects of the underlying DOS. Without this, Windows expectations for DOS is not a "level playing field."

However, not everyone agrees that companies should be required to replace tying arrangements with documentation. For example, Robert Bork, a well-known judge whose views were closely heeded

boss at the University of Chicago School of Economics in a section of his *The Intelligent Paradox* (1978) devoted to "Technological Interdependence or the 'Protection of Goodwill'" says that "the manufacturer is likely to understand the technical problems of his machines better than assesses" and that "The warning about the secrets and the continual pole to be exposed to [make sure that] are complied with is also very likely to be more expensive than supplying the related good oneself."

In other words the "transaction costs" are too high for proper documentation and specifications [Proper interfaces are too expensive] and the production of technically interdependent products is best handled within a firm "supplying the related good oneself" is a rational matter rather than leaving it open to market "contracts in the free market" which is apparently too inefficient. It follows from this, of course, that so-called "Chinese Walls" between different divisions of such a firm are in vain essays. Likewise it would follow that issues of an undocumented function is a moot issue.

But there need to be "Chinese Walls" not only because Microsoft keeps claiming they exist, when he was sued by Microsoft over its monopoly position as operating systems supplier to leverage its competitive position in applications under—but not because this is *good commercial practice*. These supposed Chinese Walls are really nothing more than weak software engineering such as "firewalls" narrow and well documented interfaces. Despite the claims that isolating components are a more inexpensive alternative to proper documentation and public interfaces engineering experience tells us otherwise.

But ought for Microsoft to be able to use undocumented DOS calls in its Windows product? Is Microsoft obligated to publish documented calls or to erect a "Chinese Wall" (or a well defined, public interface) between DOS and Windows? On the one hand, these are both pieces of system software. Windows is not unlike your favorite spreadsheet or application. On the other hand, Windows competes with DOS (before Windows 3.0 DOS was the GUI) wars with desktop shells from other companies. Microsoft can make its shell work better on top of DOS by better incorporating knowledge of DOS internals into Windows and by making DOS more Windows compatible. No other company has that double benefit. Should Microsoft have this luxury or should it be required to spell out exactly how its products fit together?

Microsoft Windows Uses Undocumented DOS

Let's examine the DOS-Windows connection in greater detail. To properly cover this subject would require a whole separate book. We know because we wrote several hundred pages already and then set them aside for another book. But certainly we can get some idea of what DOS and Windows have to say to each other. As everyone knows, Windows is not a DOS program that you start by typing WIN at the DOS prompt or put in your AUTOEXEC.BAT file. Actually, Windows is a wide collection of programs and drivers that WIN.COM kicks off.

Instead, Windows is a protected mode, multitasking, graphical, windowed, dynamic linking, device independent Windows operating environment. Some of the features of the single tasking, real mode MS-DOS operating system is tricks to access these features. It surprisingly intimate knowledge of how MS-DOS works. It uses knowledge that Microsoft uses to implement Windows but does not document for other vendors.

Let's look at exactly what undocumented DOS calls Windows makes. How do you find out what DOS functions [are] undocumented? Well, you could write a program to pore over DOS source code, if you could get access to the source code. You could also look at Chapter 6 of this book, "Disassembler," but there is an easier way if you're just interested in what DOS calls a program makes. The architecture of MS-DOS lets you hook into system interrupts, including INT 21h itself. What we will write a program that hooks INT 21h and other DOS entry points and that tells us whenever a program makes an undocumented DOS call.

David Maxey designed the program INTRSPY for this very purpose. It is an event driven, snoopy, Windows-based debugger that you can also use for many tasks that have nothing to do with undocumented DOS. Chapter 5 of this book describes a new, enhanced version of this program in detail. You

can write an INTRSPY script that logs information to a file every time a program makes an undocumented DOS call. A very simple INTRSPY script that monitors some undocumented DOS calls (but that doesn't use many INTRSPY features) appears in Listing 1-2. This script also only traps a few undocumented DOS calls. For example, the script logs information every INT 2Fh critical section functions because Windows generates so many of these functions that they would obscure the INTRSPY results better. Windows makes many other undocumented DOS calls besides those that UNDOC.SCR traps, but the few that UNDOC.SCR does capture are typically a handful.

It is important to underscore that what we're discussing here is undocumented DOS calls made by Windows. DOS is a separate subject from that discussed in *Undocumented Windows*. That book covered the subject of undocumented Windows itself. It also handled the controversial subject of which Microsoft applications use these calls. That book did not, however, go into how Windows itself works on top of DOS or what undocumented DOS functionality Windows relies upon.

Listing 1-2: INTRSPY Script UNDOC.SCR

```
;;
;; UNDOC.SCR
;;
intercept 21h
    function 52h on_exit output  "2152  Get List of Lists    ES "   BX
    function 55h on_entry output  "2155  Create PSP    DX  ,   SI
    function 53h on_exit output  "2153  Translate BPB
    function 5dh subfunction 06h
        on_exit output  "25d06  Get DOSSWAP    DS     SI
    function 60h
        on_entry output "2160: Canon File: " (DS:SI->byte,asciiz,64)
        on_exit same[ne]    =>   (ES DI >byte,asciiz,64)
;;
;; Use the next functions and ints 20h and 27h to show which
;; program made the undoc DOS call, and to show termination
;;
    function 4bh
        on_entry
            output "---------------- ++ -----"
            output (DS:DX->byte,asciiz,64)
    function 4ch on_entry output  "--- - ------------------"
    function 31h on_entry output          "-- TSR - - -------"
intercept 20h on_entry output "--"
intercept 27h on_entry output "---------- TSR -----------"
;;
;; Too many int 2Ah to show.  Could use INTRSPY counters though
;;
intercept 2fh
    function 13h
        on_entry output "2F13  Set Disk Handler " DS ":" DX
        on_exit same[ne] " (Prev: " DS ":" DX ")
```

Figure 1-6 shows output from INTRSPY when starting Windows 3.1 Enhanced mode under MS-DOS 5.0.

Figure 1-6: Selected Windows 3.1 Enhanced Mode Undocumented DOS calls

```
 C:\WIN31\WIN.COM
2152  Get List of Lists: 0116:0026
2152: Get List of Lists: 0116:0026
------------------------
 C:\WIN31\system\win386.exe
2F13: Set Disk Handler 338A:1AC5 (Prev  F000:9C13)
2F13: Set Disk Handler F000:9C13 (Prev  338A:1AC5)
2F13: Set Disk Handler 338A:0AB8 (Prev  F000:9C13)
2F13: Set Disk Handler F000:9C13 (Prev  338A:0AB8)
```

```
2152: Get List of Lists* 0116:0026
2152  Get List of Lists  0116:0026
2F13  Set Disk Handler 338A 0087 (Prev  F000:9C13)
2F13  Set Disk Handler F000 9C13 (Prev* 338A 0087)
    tons of 2F/13 calls
2152: Get List of Lists* 0116:0026
215D6, Get DOSSWAP, 0116:0320

 C:\WIN31\system\KRNL386.EXE
2152: Get List of Lists  0116:0026
2155: Create PSP: 5576, 0100
```

As I've said before, we see that when starting Windows in Enhanced mode WIN.COM runs WIN-SOFT.EXE. WIN386.EXE is a collection of Windows virtual device drivers (VxDs). A few key VxDs are the Virtual Machine Manager (VMM), the MS-DOS Manager (DOSMGR), the MS-DOS Network Manager (DOSNET), the Virtual 8086 Mode Memory Manager (V86MMGR), the Virtual Programmable Interrupt Controller Device (VPICD), and the Virtual Block Device (BlockDev).

For the purposes of examining the interaction between DOS and Windows, the key VxD is as you might expect, DOSMGR. When trying to understand why Windows calls the functions it does, I turn to DOSMGR as where I would spend most of my time. It isn't enough to say that Windows calls DOS 21h and sometimes 2Fh DOS calls because there really isn't any such single call in Windows. Instead, Windows is a collection of many separate programs, libraries, drivers, and initialization files. It is important to point out the undocumented DOS calls made by Windows down to specific files.

Another VxD, KRNL386.EXE, makes KRNL386.EXE what is a Windows DLL containing the kernel portion of the Windows application programming interface (API). For example, KRNL386 contains the WinExec() function, the API call that knows how to load Windows executables. Windows device drivers, such as the ones in VxDs, and DLLs. KRNL386 has its own DLLs like USER and GDI. The INT 2Fh AX=1684h, BX=0005h call to the DOS kernel routine (INT 21h AH=33h, AL=05h) is used to get the location of the kernel being accessed. Knowing Windows EXE, DLL, DRV, and SYS files that a program is running in the SYSTEM.INI shell setting comes up. By default, this is PROGMAN.EXE, the Program Manager, not just as COMMAND.COM isn't the only possible shell for MS-DOS. PROGMAN.EXE is the only possible interface for the Windows desktop.

In Listing 2-1, I've found the Windows, or rather various parts of Windows, calls INT 2Fh AH=12h, SubFunction=SysVars; INT 21h AH=50h, Set PSP; INT 21h AX=5D06h, Get SDA; and INT 21h AH=52h, Get List of Lists. As noted earlier, Windows makes many additional undocumented DOS calls, but the few shown here are enough.

Let's briefly try to see why Windows makes these calls. INT RSP only shows *what*. To see *why*, you need either to disassemble Windows with a product such as Windows Source from V Communications (www.vcom.com) or Windows under a debugger such as Soft-ICE from Nu-Mega.

WIN.COM Walks the SFT

Why does WIN.COM call the undocumented Get SysVars function, INT 21h AH=52h? This turns back to the description of SYSVARS, the internal SysVars structure, where I said that the DOS data segment (DS) contains pointers to many other key internal DOS data structures, such as the Memory Control Block (MCB) chain, the System File Table (SFT) chain, the Current Directory Structure (CDS), and several others. For this reason, this structure is sometimes called the List of Lists.

WIN.COM next makes various Device calls (INT 21h AH=44h). Some of these are only issued once, while others are issued many times, such as when running Windows in Standard mode; others, mainly Ioctl calls (INT 21h AH=44h), are issued every time the VARD code occurs every time someone types a WIN. As once explained in the disassembly of WIN.COM shows that WIN.COM uses the SysVars table to find the first SFT. WIN.COM then walks the SFT chain, counting the number of available files, to

ensure that you have at least FILES=30 on your system. Figure 1-7 shows disassembled DOS code. If this code looks strange, you may want to read Chapter 3 and then come back here.

Figure 1-7: WIN.COM Walks the SFT Chain

```
4C40:1828       mov ah,52h
4C40:182A       int 21h                         ; get sysvars into ES:BX
4C40 182C       xor ax,ax                       ; init number of files = 0
4C40 182E       les bx,dword ptr es [bx+4]      ; sysvars[4] ptr to first SFT
4C40 1832   DO_NEXT_SFT:
4C40 1832       add ax,es:[bx+4]                ; SFT[4] is number of files
4C40 1836       cmp word ptr es [bx],0FFFFh     ; SFT[0] ptr to next, at end?
4C40 183A       je  short DONE                  ; if so, done
4C40 183C       les bx,dword ptr es [bx]        ; if not, walk linked list
4C40,183F       jmp short DO_NEXT_SFT
4C40,1841   DONE:                               ; done walking list of SFTs
4C40 1841       sub ax,1Eh                      ; 1Eh = 30
4C40 1844       jnc short loc_ret_0110          ; Complain if not FILES=30+
```

This code is very similar to the SHOWSFT example in Chapter 8. In the sense that its use of undocumented DOS is a big deal, it almost seems trivial. You might ask, "Is this what all this 'undocumented' fuss is about?" The answer is yes. Many of the ways Microsoft uses undocumented DOS seem trivial in the same way.

But think for a moment about how you would get the FILES value if *documented* ways of doing so weren't open to you. (Open the CONFIG.SYS file and read the value.) Parsing that text file is totally unreliable. A user could have booted the system with a new FILES number, but you can't read CONFIG.SYS, thought about rebooting. Instead, look at how Windows Multimode DOS and Windows 95's Compatibility Box VDMs (see Chapter 15) get the value. It makes a big difference to the stability of a program. Note: This is not to imply that Windows is an art science.

BlockDev and INT 2Fh Function 13h

Back in Figure 1-6, the first set of calls from WIN386 is to INT 2Fh AH=13h, which, as noted in the appendix, is the DOS Set Disk Interrupt Handler function. Even though WIN386 is making this call, BlockDev is new to Windows 3.1. It replaces the Windows 3.0 virtual hard disk device. The FastDisk support in 3.1 (which provides 32-bit disk access) uses BlockDev. BlockDev needs to hook the DOS disk interrupt (INT 13h), but it needs to do so in a way that the operating system doesn't cut disk caches and other features that already hooked INT 13h out of the system. BlockDev's INT 13h hook must be *transparent*. Via INT 2Fh AH=13h, BLOCKDEV provides a way for a virtual device to hook INT 13h, using this function, BlockDev can get its hooks in *before* existing INT 13h handlers.

For a more complete discussion of BlockDev, FastDisk, and INT 2Fh function 13h, see Chapter 14 of Geoff Chappell's book *DOS Internals*.

DOSMGR: Windows' Connection to Undocumented DOS

The other WIN386 undocumented DOS calls (Figure 1-6) are coming from the DOSMGR VxD. This is where we get to the heart of Windows' connection to undocumented DOS. Just a few calls appear in Figure 1-6, but you'll see these functions return pointers to structures in the DOS data segment. The functions open up a vast amount of DOS internals to Windows.

In the disassembly in Figure 1-8, you can see that DOSMGR stores the return value of INT 21h AH=52h in several different ways. After calling INT 21h AH=52h, DOSMGR makes a call via an Exec Int handler provided by VMM (see Chapter 3). The ES register provides a flat 32-bit way to get the value of DOS's data segment. DOSMGR stores this value in a variable we have called DOS_DS. DOSMGR also shifts the value left four bits to form a 32-bit linear address. DOS_SYSVARS_LIN. To this it adds BX to form a 32-bit linear address to the SysVars table, SYSVARS_LIN.

Figure 1.8 DOSMGR Saves Away SysVars

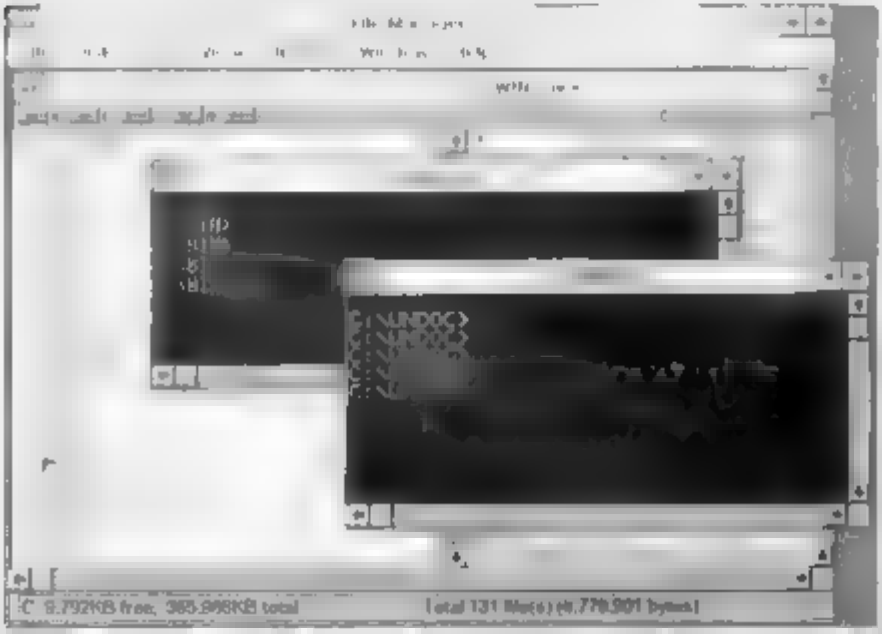
```
_SAVE   mov [ebp.Client_AX],5200h   ; calling INT 21h AH=52h
DSAA4   mov eax,21h                 ;  Get SysVars Table Address;
DSAA9   VMMCall Exec_Int            ; via VMM Exec_Int function
DSAAF   mov eax, [ebp.Client_ES]
_SA     mov DX, [ebp.eax]           ; save ES from 21/52, ignoring BX
        shl eax,4                   ES << 4
        mov ax,[ebp.Client_BX]      ; move in the zero-extend
DSAB8   mov DX, word ptr [eax]      32-bit linear address of DOS DS
SA4     add eax,ebx                 now add in BX from 21/52
SA6     mov SYSVARS, eax            32-bit linear address of Sysvars
```

[illegible] DOSMGR [illegible] DOS [illegible] DOSMGR [illegible] SYSVARS [illegible] Using [illegible] DOS [illegible] DOSMGR [illegible] DOS [illegible] the [illegible] DOSMGR [illegible]

[illegible] DOS [illegible] DOS [illegible] VxD [illegible] known as the Shell [illegible] DOS [illegible] DOS [illegible]

[illegible] VM [illegible] DOS [illegible] DOS [illegible] DOS [illegible]

Figure 1.9 Windows Enhanced Mode—Multiple CDS in Action



But there is only one copy of DOS. How does Windows Enhanced mode manage this? DOSMGR is the component of Windows responsible for maintaining the illusion that DOS is a multitasking operating system. Among its other responsibilities, when Windows starts the DOS extender for Windows Enhanced mode, DOSMGR serves as a virtual DOS device, managing contention from multiple VMs for access to a single copy of DOS. Each DOS box thinks it has its own copy of DOS and DOS thinks it is running only one single-minded application that happens to like to wreak drives and directories a lot.

One of the problems is Windows wants to service these calls each in the context of the VM. Normally memory allocated before Windows exists is global—that is, it is mapped at the same location and is shared by each VM. Thus global memory is normally the same for all VMs. Some examples of this memory include ISRs, device drivers, and the data structures DOS uses. Unfortunately, the CDS would normally be global, shared by all VMs. To prevent the undesired effect shown in Figure 1-9, Windows Enhanced mode creates instances of CDS. Instance data is the mechanism that lets Windows know which pieces of global memory should be private to each VM, while still located at the same address in each VM.

To instance the CDS, DOSMGR passes the address and size of the CDS to the VMM Add_Instance function. But how does DOSMGR know where the CDS is located? By using undocumented DOS internals. In Figure 1-8, DOSMGR issued INT 21h function 52h to get a pointer to SysVars, as in Figure 1-10. DOSMGR uses SysVars to obtain pointers to the DOS device chain, the CDS, and the DOS LASTDRIVE value, all of which are kept in SysVars (see Chapter 2).

At the start of Figure 1-10, DOSMGR calls the VMM Get_Cur_VM_Handle function, which returns in the EBX register the handle of the current virtual machine. VM 1 is always the currently running DOS box or, if the System VM would again receive CPU time if Windows operations run. This VM handle is the 32-bit linear address of the VM control block. VM.CB is a structure which contains, at offset 4, the 32-bit base address of the DOS area for System VM's memory. Adding this base address to the value 20 at offset 4 results in the 32-bit linear address of memory that is used as DOS for System VM. Execution passes to the code in Figure 1-10 (Figure 1-11 has the address of the CDS within a given VM by following a chain of addresses. The SI Get_Sys_VM_Info call in Figure 1-10 loads EBP with the address of the System VM control block. Chapter 3 discusses this somewhat complicated but important topic in much detail.

Figure 1-10: DOSMGR Saves Away Values from SysVars

```
; Inside Initialization code
05CBF   VMMCall   Get_Cur_VM_Handle          ; get current VM handle into EBX
05CC5   mov ebx,dword ptr [ebx+4]            ; VM[4]=VM's base addr in memory
05CC8   add ebx,dword ptr SYSVARS_LIN        ; make a flat 32-bit linear addr
05CCE   mov eax,dword ptr [ebx+16h]          ; sysvars[16h] is CDS ptr
05CD1   movzx ecx,ax                         ; ecx = zero-extend (word) CDS ofs
05CD4   shr eax,10h                          ; eax = segment, discard offset
05CD7   shl eax,4                            ; linear addr of CDS segment
05CDA   add eax,ecx                          ; add in CDS offset
05CDC   mov CDS_LIN,eax                      ; 32-bit linear addr of CDS
05CE1   movzx eax,byte ptr [ebx+21h]         ; sysvars[21h] LASTDRIVE
05CE5   mov LASTDRIVE,eax
05CEA   mov eax,dword ptr [ebx+22h]          ; sysvars[22h]=NUL dev (not ptr)
05CED   mov NEXT_DRIVER,eax                  ; device drv[0]=seg of next drvr
;  ...
```

As an interesting side note, it is worth pointing out that DOSMGR sets up these variables once and doesn't check SysVars again. The code in Figure 1-10 is from the DOSMGR initialization and is discarded once Windows is up and running. DOSMGR continues to use variables like CDS_LIN, LASTDRIVE, and NEXT_DRIVER throughout the entire Windows session.

However, DOS tools such as the QEMM programs FILES.COM and LASTDRIV.COM resize and move DOS internal structures like the SFT and CDS. The whole point is to run FILES or LASTDRIV *after* LOADHI. Chapter 2 presents XLASTDRV, a clone of Quarterdeck's LASTDRIV. These programs work by updating the pointers in SysVars. But since DOSMGR only checks SysVars once, DOSMGR can't set up for the SFT or CDS pointers to change, and it isn't prepared for the value of LASTDRIV within SysVars to change either. So while you can run FILES or LASTDRIV before Windows loads, running them within an Enhanced mode DOS box is a recipe for disaster. One of Quarterdeck's technical reviewers writes, "Only an idiot would expect that to work." These programs alter SysVars as things change, but Enhanced mode is running, which means that all VMs have write-protected copies of these SysVars pointers. We'll take advantage of this fact in Chapter 3 in a Windows program, UNLASTDRV.COM, that displays the CDS in every VM. See Listing 3-2.

DOSMGR's sophisticated approach to the information it gets from SysVars, using pointers to the CDS, SFT, and so on, and so on, remains places that it's difficult to summarize. The use of multiple virtual DOSes by DOSMGR is far from trivial. The struggle that DOSMGR makes to INT 2Fh APIs exposes a huge amount of DOS internals to DOSMGR, making it possible for DOSMGR to keep as many DOS boxes relatively happy on top of a single copy of DOS.

CON CON CON CON CON

However, not everything DOSMGR needs to manipulate DOS internals is available in SysVars. For example, while SysVars contains a pointer to the SFT chain, and DOSMGR can determine the number of SFT entries by walking the SFT chain (just as WINCOM.LL1 does in Figure 1-7), SysVars does not provide the size of an SFT entry. DOSMGR needs to know the size of an SFT entry. Unfortunately, this size changes from one DOS version to the next (see Chapter 8 and the Appendix). Rather than using a lookup table to specify the size of an SFT entry for each supported DOS version, an SFT entry is 38h bytes in DOS 4.0, 3Bh bytes in DOS versions 3.1–3.3, and 3Bh bytes in 3.0. DOSMGR figures out the size of an SFT entry by opening CON five times, searching the first 512K of memory for the string CON, and then measuring the space between the first occurrence of CON and the next and second. DOSMGR then uses this space between CON to CON as the size of an SFT entry.

KRNL386 and KRNL286 use this same found-by-trial-and-error technique (see as part of *preparing* the SFT to get ready to run DOS boxes. This technique is fragile because it is success for something to go wrong. Geoff Chappell reports that Power Away, a hard disk backup utility, creates a device driver with the string "CON CON CON CON CON" in it. DOSMGR and KRNL386 found the string and thereafter assumed that SFT entries were four bytes wide!

Memory-management programs such as QEMM and 386Max contain options to move the SFT entries to upper memory. For example, you can specify a command-line option. Because DOSMGR won't find the string of CONs in the first 512K of memory, these utilities can keep Windows from loading. Before starting Windows, you must run a program that moves the SFT. Windows 3.1 can fail with the message "Unsupported DOS version" or hang. Some DOS clones that use alternative SFTs.

To work around this incompatibility of memory managers relocating the SFT tables to upper memory, Bob Moore, Symantec's SFT Czar, posted on January 12, 1993, published a batch file that creates a string of CONs 38h bytes apart in conventional memory. You might wonder why DOSMGR doesn't find a prompt during these scrutinized SFT entries instead of the genuine ones. Fortunately, DOSMGR uses the fact CONs just forget the size of an SFT entry. Then uses function 52h to find the entries themselves.

The Undocumented DOSMGR Callout API

As a more important example of how DOSMGR must sometimes supplement its use of undocumented DOS structures, let's return to the CDS table. To use the table, DOSMGR must know the size of an individual CDS entry for a single drive. Recall that to instance the CDS, DOSMGR must

pass CDS LIN to AddUniqueDirectory together with the size of the CDS record. ANSI DRIVE.SYS knows the number of CDS entries but doesn't know how many bytes each occupies.

In most utilities that manipulate undocumented DOS data structures, knowledge of the size of the data structure is crucial. For example, the VLASTDRV program in Chapter 2 uses the DOS version number to determine whether a CDS entry is 88 bytes or 58 bytes. It's also perhaps true that this kind of information tends to change less frequently and that it leaves Windows developers with more knowledge of DOS internals. DOSMGR uses another mechanism to find the size of a CDS entry, as a supplement to use of undocumented DOS. DOSMGR has a private interface to DOS 3.0 and higher.

As each VxD loads, it receives a VxD initialization broadcast. INT 2Fh AX=1607h with its VxD ID number in BX. VxDs that issue broadcasts or that provide services to other programs have device ID numbers assigned by Microsoft. VMM, for example, has VxD ID 1, and DOSMGR has VxD number 15h. Walk, Microsoft's Windows Device Driver Kit (DDK) 3 *and Device Migration Guide* (MDG) clearly documents the INT 2Fh AX=1607h VxD initialization broadcast. Microsoft says absolutely nothing about the actual broadcasts or API functions supported by any of the VxDs built into Windows. In other words, Microsoft documents every component INT 2F mechanism you want to find out what notifications or APIs a piece of Windows code (as DOSMGR) provides, the DDK is silent.

Microsoft uses the DOSMGR VxD callout (INT 21h AX=168Fh BX=xxxx) as a private interface between MS-DOS and Microsoft Windows. A Microsoft internal document (API for Correct MS-DOS Instance Data) related to Windows 3.1 describes how to get the undocumented data structures that, apparently, it was broadly assumed would be documented in the Quick Help files for the Windows 3.1 DDK. Actually, it's an API for another purpose: instance data. MS-DOS 5.0 is the first DOS that can run without Microsoft's normal document, several programmers have discovered DOSMGR and used MS-DOS to see what they have to say to each other.

The DOSMGR VxD callout (INT 2Fh AX=1607h BX=15h) provides several subfunctions specified in the CX register. Table 1.1 lists these subfunctions. For further details, see the appendix entry for INT 2Fh AX=168Fh as well as Geoff Chappell's book *DOS Internals*.

Table 1.1. DOSMGR VxD Callout Subfunctions

0	Query instance processing, get patch table
1	Set patches in DOS
2	Remove patches in DOS
3	Get size of DOS internal data structures
4	Query instanced data structures
5	Get device driver size

DOSMGR issues these calls, see for example the code in Figures 1.11 and 1.12, and MSDOS.SYS looks INT 2Fh and responds to these calls. Yes, MS-DOS should be called to look at itself. For some of the functions, DOS is expected to pass back a DX:AX value that checks "signature" of 0AE29h. The implementation of several calls in DOS 5.0 and 6.0 only implement subfunctions 0, 3, and 4. The implementation of 4 in DOS 5.0 and 6.0 always returns 0 and indicates that no DOS data was requested via this interface. On the other hand, the implementation of MS-DOS 7 (the Windows 95 version) and subsequent DOS has taken care of instancing DOS internal data structures itself. DOSMGR is ready for this as shown in Figure 1.11.

Figure 1.11: DOSMGR Determines If MS-DOS Does Instancing

```
0583C       mov [ebp.Client_AX],1607h ; VxD callout
05842       mov [ebp.Client_BX],15h   ; 15h = DOSMGR
05848       mov [ebp.Client_CX],4     ; subfunc 4 = query inst data struct
0584E       mov eax,2Fh
05853       VMMCall  Exec_Int         ; do INT 2Fh
```

```
05B59       cmp [ebp.Client_AX],0B97Ch , make sure got funny signature
05B5F        ne short QUERY_PATCH_DOS
05B61       cmp [ebp.Client_DX],DA2ABh , make sure got funny signature
05B67        ne short QUERY_PATCH_DOS
05B69       movzx eax,[ebp.Client_BX] , bit mask of instanced items
05B6D       mov DOS_STRUCTS_INST,eax
      QUERY_PATCH_DOS:              , now try subfunc 1
```

This subfunction 1 of DOSMgr function 27h gets the size of internal DOS data structures. It's the subfunction used by DOSMGR.EXE prior to DOSMGR.SYS. This subfunction is currently used only to get the size of a CDS entry.

Figure 1-12: DOSMGR Determines the Size of a CDS Entry

```
06180       mov [ebp.Client_AX],1607h , VxD callout
06191       mov [ebp.Client_BX],15h   ; 15h = DOSMGR
06197       mov [ebp.Client_CX],5 , subfunc 5=get size of DOS data struct
0619D       mov [ebp.Client_DX],1     ; 1 = get CDS size
061A3       mov edx,0
061A8       VMMCall Exec_Int
061AF        cmp [ebp.Client_AX],0B97Ch , got weird signature?
061B6        jne short NO_CALLOUT          ; if not, figure out CDS by hand
061B8       cmp ebx,'SUOD'                 ; got weird signature?
061BE        jne short NO_CALLOUT          ; if not, figure out CDS by hand
061C0       movzx eax,[ebp.Client_CX] , call supported - get CDS size
061C4        jmp short GOT_CDS_SIZE        , yes here, was supported
061C6   NO_CALLOUT:                       ; I'll do it myself without any help
061C6       mov eax,51h                   , CDS size = 51h bytes
061C9        cmp byte ptr DOS_MAJ,4
061D0        jb short GOT_CDS_SIZE         ; if DOS 3 skip next
061D2       add eax,7                     ; add 7 bytes to CDS size for DOS 4+
061D5   GOT_CDS_SIZE:
061D5       mov CDS_ENTRY_SIZE,eax
061DA       mul dword ptr LASTDRIVE
061E1       mov CDS_SIZE,LASTDRIVE*CDS_ENTRY_SIZE
```

Once the size of the DOSMgr internal data structure is known, memory must be allocated for it. The DOSMGR.SYS device driver does this by calling DOSMgr function 27h, subfunction 0. DOSMgr then allocates memory for the DOS internal data structures. For example, the DOSMgr function 27h, subfunction 0 for the CDS call for DOS 5.0 and 6.0 is shown in DOSMGR.SYS as it looks in the work buffer, as shown in Figure 1-13, which is a continuation of Figure 1-12.

Figure 1-13: DOSMGR Instances the CDS

```
061D5   GOT_CDS_SIZE:
061D5       mov CDS_ENTRY_SIZE,eax                , size of a CDS entry
061DA       mov dword ptr LASTDRIVE               , number of entries
061E0       mov CDS_SIZE,eax                      , size of entire CDS table
061E5       mov edx,dword ptr DOS_PSP             , 0-base linear addr of CDS
; DOS_STRUCTS_INST set = Figure 1-13
061EB       test    byte ptr DOS_STRUCTS_INST,1 , does MS DOS do the work?
061F2       jnz short MSDOS_DOES_INST             ;   jump if so
; ESI holds a pointer to an InstDataStruc
061F4       mov dword ptr [esi+8],edx             , CDS_LIN
061F7       mov dword ptr [esi+0Ch],eax           , CDS_SIZE
061FA       mov word ptr [esi+10h],200h           , Inst type ALWAYS field
06201       push    0
06203       push    esi                           , push InstDataStruc
06204       VMMCall AddInstanceItem               , call VMM function
0620A       add esp,8                             ,   (cdecl call)
0620D       or  eax,eax                           , did function succeed?
0620F       jz  short FAILURE
```

```
06211   MSDOS_DOES_INST:
; use tables from DOSMGR 2F/1607/15 callout
;...
0628C   FAILURE
0628C       VMMCall Fatal_Memory_Error          ; Windows can't run
```

This code is [illegible] illustration of the [illegible] information-sharing data structure that DOS and Windows programmers use to communicate. It's an instructive look at what DOS source programming will increasingly look like in years to come.

But there's something [illegible] about the DOSMGR callout API. For example, since MS-DOS uses the API to pass DOSMGR the segment of DOS data, why not also pass it the size of other DOS internal data structures, especially the SFT? We already saw the ridiculous "CON CON CON CON CON" ploy that DOSMGR makes to find the size of the SFT entry. Given that the DOSMGR callout API exists, it's [illegible] DOSMGR to [illegible] that.

Perhaps the DOSMGR callout API was [illegible] to solve problems running Windows on OEM versions of MS-DOS. One can't [illegible] speculate, for example, that the Quick-CDN/Size function really was needed [illegible] NEC versions of DOS. But when we examine the DOSMGR interface, it also seems [illegible] could be used to [illegible] running a real-time kernel alongside Windows or at least DOSMGR [illegible] from our knowledge of DOS internals alone, though I believe [illegible].

There have been persistent [illegible] that engineers at Microsoft have [illegible] calls created "specifically" for versions of Windows running in protected mode, [illegible] object management. For example, Microsoft [illegible] that Windows/386 2.1 was [illegible] DPMI, and that several [illegible] undocumented [illegible] on OS/2 2.0 [illegible] the Windows kernel [illegible] the DOS Protected Mode Interface (DPMI) chapter. Matt Pietrek notes in his *Windows Internals* (p. 90) that Windows bypasses DPMI. This means that IBM must [illegible] Windows 3.1 [illegible] to [illegible] different [illegible] WIN-OS/2 (see Chapter 4). However, Pietrek points out that the DPMI [illegible] version of the Windows kernel [illegible] Windows code, and that this is the reason Microsoft bypassed DPMI. In [illegible], Microsoft appears [illegible] have alternative motives for [illegible] Windows from portable [illegible] to [illegible] engineering reasons.

[illegible] was easy to [illegible] whether the [illegible] had [illegible] the DOSMGR interface isn't an example of Windows [illegible] portability. On the [illegible] DOS 5.0 or higher workalike must [illegible] the DOSMGR [illegible] in order to run Windows 3 enhanced mode. On the other hand, since the DOSMGR interface is [illegible] DOS [illegible] to [illegible] structured [illegible] such a way that [illegible] Windows [illegible] [illegible] of DOS internals [illegible] to [illegible] developing Windows [illegible] DOS [illegible]. The DOSMGR callout API [illegible] is [illegible] [illegible] to bind Windows and MS-DOS more tightly together.

The program in Listing 1-3, NODOSMGR.C, [illegible] this point. NODOSMGR hooks INT 2Fh and [illegible] Windows [illegible] INT 2Fh [illegible]. NODOSMGR uses the chain [illegible] to [illegible] through all calls except DOSMGR callout API calls (AX=1607h BX=15h). [illegible] processes the [illegible] MS-DOS [illegible]. Windows calls to INT 2Fh AX=1607h BX=15h. NODOSMGR [illegible] the effect of [illegible] Windows on a version of DOS 5.0 or higher, which is a requirement [illegible] undocumented DOSMGR interface.

Listing 1-3. NODOSMGR.C

```
/*
NODOSMGR.C -- Simulate DOS 5+ without DOSMGR callout API
From  Undocumented DOS , 2nd edition (Addison-Wesley, 1993)
Andrew Schulman, June 1993
bcc -P- -2 nodosmgr.c
*/

#include <stdlib.h>
#include <stdio.h>
#include <process.h>
#include <dos.h>
```

```
#pragma pack(1)

typedef struct {
#ifdef __TURBOC__
    unsigned short bp,di,si,ds,es,dx,cx,bx,ax;    \
#else
    unsigned short es,ds,di,si,bp,sp,bx,dx,cx,ax;     /* same as PUSHA */
#endif
    unsigned short ip,cs,flags,
    } REG_PARAMS,

volatile unsigned dosmgr_calls = 0;
int pass_through[10] = { 0 };   /* list of DOSMGR calls ok to pass to DOS */

#define DOSMGR_MAGIC_DX     0xA2AB
#define DOSMGR_MAGIC_AX     0xB97C

void interrupt far int2f(REG_PARAMS r);
void (interrupt far *old)(void);

void fail(char *s) { puts(s); exit(1); }

main(int argc, char *argv[])
{
    int i, func;

    if (argc < 2) fail("usage  nodosmgr [win] <func list to pass through>");

    for (i=2; i<argc; i++)
        if ((func = atoi(argv[i])) < 10)
        {
            pass_through[func]++;
            argv[i] = (void *) 0;
        }

    old   (void (interrupt far *)(void))  dos_getvect(0x2F); // hook 2F
     dos_setvect(0x2F, int2f);
    spawnvp(P_WAIT, argv[1], &argv[1]);     // run command (e.g., Windows)
    _dos_setvect(0x2F, old);                // unhook 2F

    printf("%u calls to DOSMGR 2F/1607/15 interface\n", dosmgr_calls);
    return 0;
}

void interrupt far int2f(REG_PARAMS r)
{
    if ((r.ax == 0x1607) && (r.bx == 0x15))
    {
        dosmgr_calls++;
        if (pass_through[r.cx])
        {
            if (r.cx == 1)
            {
                r.bx = r.dx;                // do just what DOS does
                r.dx = DOSMGR_MAGIC_DX;     // but don't pass down to DOS
                r.ax = DOSMGR_MAGIC_AX;
            }
            else
                _chain_intr(old);
        }
        // otherwise, don't pass down to DOS
    }
    else
        _chain_intr(old);
}
```

When NODOSMGR.WIN is run on MS-DOS 6.0, Windows starts to come up, but then Windows aborts with the message "ERROR: Unsupported MS-DOS version." This is precisely the message that DOS 5.0 or higher workalikes get if they fail to implement the DOSMGR interface.

NODOSMGR has an option to pass through a specified DOSMGR subfunction. For example running NODOSMGR WIN 0 blocks all subfunctions except CX=0 Query instance processing see Table 1 for which is passed down to DOS. Issuing through subfunctions 0, 2, 3, 4, or 5 still results in an "ERROR: Unsupported MS DOS version" failure from Windows DOSMGR.

However running NODOSMGR WIN 1 has an interesting effect. Windows runs! In other words at least Windows 3.0 through 6.0 under MS DOS 5.0 to 6.0 calls DOSMGR without problems. Set patches in DOS see Table 1 appears to be absolutely necessary. And MS DOS's implementation of this function is trivial so trivial in fact that NODOSMGR does not even bother passing this function down to DOS. As you can see in Listing 1-3, NODOSMGR 0 merely sets BX to DX and puts the NODOSMGR magic signature in DX:AX. This is all MS DOS does in its handler for INT 2Fh AX=1607h BX=15h CX=1.

```
                        loc_4678
FOC8:4678   8BDA            MOV BX,DX
FOC8:467A   EB0F            JMP loc_468B
;  .
                        loc_468B:
FOC8:468B   B87CB9          MOV AX,B97C
FOC8:468E   BAABA2          MOV DX,A2AB
```

So, simply by passing back these magic numbers we can circumvent the "ERROR: Unsupported MS DOS version" message and allow Windows to run. At least superficially, the resulting Windows DOS configuration seems stable; we're using it now to write this chapter and have a few DOS boxes open along with Clock and Solitaire.

Of course, this is a rip-off of a piece of genuine MS DOS functionality, but it *is* sufficient. If subfunction 0 is not passed down to MS DOS, DOSMGR calls may set its own methods for patching DOS; see Chapter *DOS Internals*, Chapter 2. The result is that it's all much more sensible later. The DOS USER ID field is a 32-bit number (virtual machine ID = 1 see INT 2Fh AX=1683h) and instead of 0, it's may have some implications for task handling; see "Patching DOS". Try subfunctions 0 and 1 need to be passed down to DOS when running NODOSMGR WIN 0/1.

These results raise the question of what purpose the DOSMGR called API calls serve and what it's perhaps actual "function" is. Some clues of DOSMGR resides almost entirely in these magic numbers. This in turn raises the possibility that the real purpose of the DOSMGR call or API is to fool Windows and MS DOS 5.0+ into thinking certain data was available. The interface is a window dressing as it were. I suspect this subfunction was originally exploring.

This possibility is underscored by the fact that some pieces of the interface are not implemented by MS DOS and that some implementations are buggy. The current implementation of the interface in MS DOS 6.0 looks like this (compare Table 1-2):

```
func 0  ret cx=1, es bx -> DOS_DS:1022 (DOS var patch table)
func 1: ret bx=dx, dx ax=magic
func 2  not handled
func 3  if (dx & 1) return cx=58h (CDS entry size), dx:ax=magic
func 4  ret dx = 0 (trivial)
func 5  get device driver size from MCB, ret dx ax=magic
```

The real question is why DOSMGR requires that an underlying DOS 5.0 or higher implement this interface when DOSMGR also contains tons of hard-coded assumptions about DOS internals. While it is highly likely that this interface was designed for the sole purpose of making Windows inhospitable to other DOSes, the result is certainly that the interface constitutes yet another obstacle to Windows portability, while providing very little benefit in return.

At the same time, there's also a positive lesson to be drawn from the DOSMGR-related API. The point has been made several times in this chapter that it is *good* for Microsoft to make DOS more

a text pattern for Windows. The impression was perhaps created that this requires intimate knowledge of Windows by MS-DOS and of MS-DOS by Windows. Certainly that is the impression Microsoft wants to create. But the existence of the DOSMGR callout API, though not its current Windows implementation, shows that it would be possible to create a nice clean operating interface between DOS and Windows. Were the DOSMGR callout API taken to its logical conclusion, Windows would require no internal knowledge of DOS internals. All it would require would be an interface to DOS that handled the DOSMGR callout APIs.

Such a method would not only be good engineering practice (remember modularity?), but it would also allow operation of other DOSes under Windows, and other multitasking operating systems under DOS. Even Microsoft would benefit from such a "Chinese Wall" between DOS and Windows. Chinese Walls are notorious barriers for modularity because it would allow Windows and DOS to be changed without affecting each other. On the other hand, this problem disappears in Chicago, where Windows 4.x will not be sold separately from the underlying operating system.

Implementing DOSMGR Functions

The variable named CDS_SIZE in Figure 1.13 is used throughout DOSMGR. For example, DOSMGR uses it to implement the low-level function shown in Figure 1.14, that copies the CDS out of one VM specified in ESI to another specified in EBX. The SHELL.ASM calls this DOSMGR routine to initialize new VMs with the CDS of the System VM.

Figure 1.14: Implementation of DOSMGR Copy VM Drive State

```
    DOSMGR_Copy_VM_Drive_State  proc    near
01E13   pushad
01E14   mov esi,dword ptr [esi+6]   , ESI=source VM, VM_CB[4]=base addr
01E17   add esi,dword ptr CDS_LIN   , linear address of source VM CDS
01E1D   mov edi,dword ptr BUFFER    , allocated with _HeapAllocate
01E23   mov ecx,dword ptr CDS_SIZE  , number of bytes in CDS
01E29   cld
01E2A   rep movsb                   , copy from source CDS to buffer
01E2C   mov esi,dword ptr BUFFER
01E32   mov edi,dword ptr [ebx+6]   , EBX=target VM, VM_CB[4]=base addr
01E35   add edi,dword ptr CDS_LIN   ,  linear address of target VM CDS
01E3B   mov ecx,dword ptr CDS_SIZE
01E41   cld
01E42   rep movsb                   , copy from buffer to target CDS
01E44   popad
01E45   retn
    DOSMGR_Copy_VM_Drive_State  endp
```

Several other documented DOSMGR functions rely on undocumented DOS. For example, DOSMGR_Add_Device adds a DOS device driver onto the device chain for a VM. The function argument is the 32bit SysVars offset 22H in the DOS data segment and the root of the device chain. To add your own device driver to the device chain, you must first find the end of the chain and link in the new device driver. DOS provides no services to do this. For the most part, DOSMGR_Add_Device only works with character device drivers. The Windows V86MMGR_VxD uses DOSMGR_Add_Device to load its associated EMM driver onto the DOS device chain, unless SYSTEM.INI includes the line NoEMMDriver=ON.

Figure 1.15 shows the implementation for DOSMGR_Add_Device. Most of the code here involves getting SysVars, getting the root of the device chain, finding the end of the device chain, and so on. The actual work of adding in the driver takes only a few lines; see the label ADD_DRIVER.

Figure 1.15. Implementation of DOSMGR Add Device

```
    DOSMGR_Add_Device   proc    near
00B9A       pushad
00B9B       mov esi,eax                 , EAX = addr of device header
```

```
00B1B       shr esi,4
00B20       shl esi,10h
00B23       mov si,ax
00B26       and si,0FFh                 ; ESI = seg:ofs ptr to new dev
00B2A       or  ebx,ebx                 ; EBX = VM handle
00B2C       jnz short GOT_VM
00B2E       VMMCall Get_Sys_VM_Handle   ; if VM=0, use System VM (global)
00B34   GOT_VM:
00B34       add eax,dword ptr [ebx+4]   ; VM_CB[4] is addr of VM memory
00B37       mov edi,eax                 ; EDI = linear addr of dev
00B39       test    byte ptr [edi+5],80h    ; dev[5] is attrib
00B3D       jz  short ERROR             ; only character devices supported
00B3F       mov edx,dword ptr LAST_DRV_LIN
00B45       or  edx,edx                 ; already have LAST_DRV_LIN var?
00B47       jnz short NEXT_DRIVER       ; if so, walk to end of chain
00B49       mov eax,SYSVARS_LIN
00B4E       or  eax,eax                 ; already have SYSVARS_LIN var?
00B50       jnz short FIND_CHAIN_ROOT   ; if so, use NUL to find dev chain
00B52       mov eax,reference_data      ; if not, another way to get sysvars?
00B57       shr eax,10h
00B5A       mov SYSVARS_LIN,eax
00B5F   FIND_CHAIN_ROOT:
00B5F       add eax,dword ptr [ebx+4]   ; VM_CB[4]
00B62       mov eax,dword ptr [eax+22h] ; in 3.1+, sysvars[22h] is NUL dev
00B65   NEXT_DRIVER:
00B65       movzx ecx,ax                ; CX = offset of next driver
00B68       shr eax,10h                 ; AX = segment of next driver
            shl eax,4
00B6E       add eax,ecx                 ; EAX   lin addr of next driver
00B70       mov edx,eax                 ; EDX   0 based lin addr
00B72       add eax,dword ptr [ebx+4]   ; EAX   flat lin addr of next drv
00B75       mov eax,[eax]               ; get far ptr to next drv
00B77       cmp ax,0FFFFh               ; if segment -1, at end of chain
00B7B       jne NEXT_DRIVER             ;   otherwise, keep going
00B7D       mov dword ptr LAST_DRV_LIN,edx  ; 0 based lin addr of last drv
00B83       mov LAST_DRV_LIN_VM,eax     ; flat lin addr of  ast drv
00B88   END_OF_DEV_CHAIN:
00B88       add edx,dword ptr [ebx+4]   ; EDX=flat lin addr of next drv too
00B8B       mov eax,[edx]               ; get far ptr to next drv
00B8D       cmp ax,0FFFFh               ; if segment -1, at end of chain
00B91       je  short ADD_DRIVER        ; if so, can add in driver
00B93       movzx ecx,ax                ; still not at end of dev chain?
00B96       shr eax,10h                 ;   try same stuff again
00B99       shl eax,4
00B9C       add eax,ecx
00B9E       mov edx,eax
00BA0       jmp short END_OF_DEV_CHAIN
00BA2   ADD_DRIVER:
; EDI holds the  linear address of the new driver header
; EDX holds the  linear address of the last driver header on the chain
; dword ptr [driver header + 0] is a real mode ptr to the next driver
00BA2       mov dword ptr [edi],0FFFFFFFFh  ;make new drv's next= -1  end)
00BA8       mov [edx],esi               ; link new drv into chain
00BAA       clc                         ; carry clear = success
00BAB   DONE:
00BAB       popad
00BAC       retn
00BAD   ERROR:
00BAD       stc                         ; carry set = failure
00BAE       jmp short DONE
    DOSMGR Add_Device   endp
```

Unlike DEVTOD this function does not call the device's initialization function. This behavior is documented in the DDK V2.0 Q&A manual. Also unlike DEVTOD this function adds a device to the end rather than to the front of the device list. As the DDK points out, this means that the service won't help replace an existing device.

The instances used in Figure 1-15 could have been set in a number of different ways elsewhere in DOSMGR. Given DOSMGR's reliance on the shifting sands of undocumented DOS, it's good that DOSMGR contains so much redundancy.

Again, the question is whether it is right for one Microsoft product, Windows, to rely so much on undocumented aspects of another Microsoft product, DOS. It is truly a good thing that Microsoft is bringing DOS and Windows closer together and integrating them so tightly, but you also have to remember that Microsoft still sells them separately. If Microsoft uses undocumented DOS calls in its own separate products such as Windows, shouldn't it document these calls? After all, the calls have proven to be useful. Doesn't it make sense to document these calls or to provide new, clean, documented interfaces with equivalent functionality, like LOCKFILE/UNLOCKFILE in Windows, gave Microsoft a gross advantage in bringing out products such as Windows? Is this advantage unfair? Remember, until this may seem like petty bickering between two companies in the operating systems business, but this is one of the most active parts of the PC software market.

Even if Microsoft is a well-regulated company that owns 90% of the highways, and that's not a major problem of ours, now imagine that Microsoft secretly uses hidden features of its highways. This is not to suggest that Microsoft's cars are better than the competition's. The competition can use these hidden features, too, but first they have to somehow find out about them. Many of these hidden features are well known and constitute a kind of folklore. But hiding them raises others' cost of using them, and there's always the danger that Microsoft will at some future date remove or change them.

Patching DOS Rather than installing the private DOSMGR call-out API mostly involves patching DOS. We really do mean patching here—not hooking an interrupt, though DOSMGR and other pieces of Windows do plenty of that, too. The API writes over bytes of DOS with REP MOVSB instructions.

In MS-DOS 5.0 and later, MSDOS.SYS responds to an INT 2Fh AX=1607h BX=15h CX=0 call from DOSMGR by passing back in ES:BX a table with pointers to six DOS internal variables: SAVEDS, SAVEBX, INDOS, USER_ID, CRITPATCH, and UMB_HEAD. These names come from the Microsoft internal documents on the DOSMGR API; presumably these names correspond to the actual variable names in the DOS source code—one of our tech reviewers writes "They do!" The patch locations are all in the same segment as the patch table itself, so only offsets are provided. Figure 1-16 shows a hex dump of the patch table in MS-DOS 5.0 and 6.0.

Figure 1-16. DOSMGR Patch Table in MS-DOS 5.0 and 6.0

```
-dw 0116:1022 1029
0116:1022  0005 05EC 05EA 0321 033E 0315 008C

Patch table at 0116:1022
DOS version 5.00
SAVEDS:     05ECh
SAVEBX:     05EAh
INDOS       0321h
USER_ID:    033Eh
CRITPATCH   0315h
UMB_HEAD    008Ch
```

What does DOSMGR do with these pointers? Here again we see the half-hearted nature of the DOSMGR call-out API. Basically, USER_ID and UMB_HEAD are the only variables of any great importance.

USER_ID is where DOS keeps the machine ID. As shown in Figure 1-17, DOSMGR's handler for the VMC Critical Init message, which VMM sends out whenever a new virtual machine is starting

up smacks the new VM's ID number into this location in DOS. DOSMGR then processes SER_ID to stamp the SFT entries for open files with the VM ID. See FILES.C in Chapter 8. We'll explain the cryptic variable names in a moment.

Figure 1-17. DOSMGR Patches the VM ID into DOS's USER_ID

```
; EBX contains the VM handle, a pointer to the VM control block (VMCB)
mov eax, dword ptr [ebx+CB_VMID]          ; get VM ID # from VMCB
mov edx, dword ptr _LIN_PATCH_uSER_ID     ; linear addr of USER_ID
add edx, dword ptr [ebx+CB_High_Linear]   ; base address for VM's memory
mov [edx], ax                             ; smack in the VM ID #
```

In Figure 1-17, DOSMGR is patching the VM ID for the new VM right into DOS's data segment. As we will see later, DOS normally sets the machine ID to 0. So whether DOS knows that Windows Enhanced mode is active or skips this step, DOSMGR gets the address of USER_ID in the DOS data segment, using the VxD's own patch table from Figure 1-16. When a new program opens a file, DOS places the program's PSP and the value of USER_ID into the file's SFT entry. Under Windows Enhanced mode, this means that each SFT entry knows not only the owner's PSP but also its VM ID. It's important to distinguish between the combination of file handle and PSP (DOS under Windows Enhanced mode uses this combination to identify the file) and VM ID (DOS needs to know that logical PSPs in different VMs can be the same, like when SYSTEM.INI sets up settings such as LoadHigh=DOSMGR.SYS). PSP fragmentation also addresses this problem. Do whatever you must to keep DOS reentrant, because DOS is always running on top of a single copy of DOS.

The code fragment in step 3 above has DOSMGR access variable blocked LIN_PATCH_USER_ID, which is the 32-bit linear address of the USER_ID patch location. VxDs are 32-bit programs so they can read and write to locations above the 1 MB address. Exception-prone addresses will be made ill-set such as MOV [LIN_PATCH_USER_ID], AX. Shown is the code that DOSMGR uses to access the LIN_PATCH_USER_ID pointer word. Equivalent code passes the same address through the steps shown in Figures 1-18. The pseudocode shown in Figure 1-18 may not be practical in some of the code shown in earlier figures.

Figure 1-18. DOSMGR Forms a Linear Address to DOS's USER_ID Variable

- Use the VMM Function Get_Def_Ptr to generate an INT 21h AH=52h clock event. It returns a pointer to the DOS SysVars table in ES:BX. Get_Def_Ptr makes these available to the Client_ES and Client_BX fields in the client register structure accessed off the EBP register. See Figure 1-8.
- Use Begin_Nested_Exec, Simulate_Int, and Resume_Exec to create a DOS DS variable.
- Shift DOS DS client word to form a DOS DS linear. 32-bit protected-mode address of the DOS data segment.
- Use Exec_Int to generate an INT 21h AX=6802h (Get DOS PSP) call. DOSMGR VxD returns a pointer to the patch table in ES:BX.
- Shift Client_ES left 4 and add Client_BX to get the 32-bit linear address of the patch table.
- Call VMM function Get_Cur_VM_Handle to get the VM handle, which is a 32-bit linear pointer to the VM control block. VMCB+4 = Offset 4 in the VMCB is CB_High_Linear, which is the 32-bit base address of the VM's memory in the Windows linear address space.
- Add the VMCB_High_Linear to the 32-bit address of the patch table to get the true linear address of the patch table within the current Windows address space. Call this LIN_PATCH_TAB.
- The remaining steps are easier to show as code.

```
mov esi, LIN_PATCH_TAB
mov ax, WORD PTR [esi+8]            ; 4th word is USER_ID
mov PATCH_USER_ID, ax
movzx eax, word ptr PATCH_USER_ID   , zero-extend into EAX
add eax, dword ptr DOS_DS_LIN       , add in linear addr of DOS DS
mov LIN_PATCH_USER_ID, eax
```

On its side of the conversation, MSDOS.SYS simply has an INT 2Fh handler that looks out for AX =1605h calls. NOEMSMGR can instead patch the INT 2Fh handler ahead of this one in MS DOS.SYS so DOS sees an INT 2Fh AX=1605h call with BX=15h. It checks the subfunction in CX, fixes up the address of a hardware table (as we saw in Figure 1-16) and sets ES:BX

Each patch program knows all the spots it needs to patch CURTDATOFF to turn on critical sections. DOS 5.0 has one and two patch points, respectively, at different locations in the DOS code. The patch consists of the byte C3h, a RET opcode, and changed it to a 50h, the PUSH AX opcode. Next to, and DOS 5.0 there's one extra byte that all the DOS critical section code shares. This variable is in the DOS data segment, which is critical for DOS in ROM because you can't patch anything in the code segment. NOEMSMGR knows course patches its location to turn on critical sections. Section CURTNEST.C program in Chapter 9 and the appendix entry for INT 2Ah function 80h in the Ralf Brown's Interrupt List tracks all of these patches when it can. "Each usually" writes one of our tech reviewers.

Finally, DMI 1.0 VxD which Windows 3.1 does not use, is the address of a word where DOS would keep its paragraph address of the last meta header in conventional memory that is the base of the open system block (SMB) chain. Its location is also instance data for each VM.

DOS Knows About Windows

As we'll explain when Windows starts up it issues a INT 2Fh call with AX=1605h, when Windows exits it issues an INT 2Fh call with AX=1606h. MS DOS 5.0 and 6.0 hook these calls to maintain for instance mode only the IN WINDOWS flag. While Microsoft documents the 1605h and 1606h broadcasts in the DDK (*Device Driver Adaptation Guide*), the documentation states that this is to notify device drivers that Windows is starting. The document simply says nothing about the importance of these calls to DOS. MS DOS must respond to these Windows calls.

MS DOS uses the INT 2Fh AX=1605h Windows initialization broadcast for a number of purposes. One is to tell Windows 3.1 Enhanced mode to start up. DOS 5.0 and 6.0 tell Windows to load the WINA20.386 virtual device driver, part of the Windows VxDMGR. MS DOS also uses the broadcast to tell Windows where to find its critical status data. Windows 3.1 provides a lot of different ways to specify status data. Again, Microsoft documents the interface in the DDK, merely taking to note that MS DOS itself uses the interface.

In DOS 5.0 the Windows broadcast was used to tell Windows about instance data and VxDs, but in DOS 6.0 it is used for all of that, whether Windows Enhanced mode is currently running. DOS does not care one way or the other about DOS Extender mode, but when Windows Enhanced mode is running, MS DOS wants to operate as a network server running. If you think about it, multiple DOS boxes in Enhanced mode are very much like multiple machines on a network. As noted earlier, DOS has a machine ID number (see Chapter 2). However, if DOS sets the IN WIN3E flag it doesn't set a machine ID number to 0, instead it uses the current DOS box's Virtual Machine ID number (see INT 2Fh AX=1683h). As we saw earlier, NOEMSMGR patches this VM ID number right into DOS, which then copies it into every SFT entry.

IO.SYS also tests the IN WIN3E flag and if Windows Enhanced mode is running, IO.SYS will make a call to the VxD NOEMSMGR. In addition to the INT 2Fh AX=1607h interface, NOEMSMGR also makes VxDs available to programs. These APIs are available even to software that, like IO.SYS and in DOS 6.0 DBLSPACE.BIN, was loaded before Windows. Basically,

VxD APIs provide a way to make a VxD look very normal to but DOS code to save 32 bit protected mode VMM and VxD code executed on the behalf see Get Version and Dispatching with 32 bit Virtual Device Drivers for Windows" *Microsoft Systems Journal* October 1992 Calling INT 2Fh AX=1684h with the VxD ID such as 1Eh for DOSMGR in BX returns a VxD API entry point The DDK documents this INT 2Fh mechanism What Microsoft does not document is the actual INT 2Fh AX=1684h API provided by DOSMGR and other VxDs built into Windows As with INT 2Fh AX=1605h and AX=1607h the DDK documents only the general mechanism not the way that Windows and DOS actually use the mechanism

The undocumented DOSMGR API has several functions 00h SYNC and 01h RESPACE int 2Fh call subfunction 1 this subfunction uses the VMM Call When Not Critical service to install a callback function that updates the tracked Virtual Machine Manager critical state variable

DOS also uses the undocumented Get Version internal flag to indicate whether to generate INT 2Ah AX=8001h and AX=8081h critical section enter/exit calls DOS skips these calls when it is used to mark uninterruptible regions of code in a preemptive multitasking operating system Unlike DoubleDOS this is usually adequate see Chapter 9 However Enhanced mode effectively turns DOS into a genuine preemptively multitasked operating system

Again while it is at first surprising to learn that DOS services disk I/O when Windows Enhanced mode is running it is important to recognize that DOS makes this change using documented function calls The Microsoft DDK documentation should just state clearly that MS DOS does it

DOSMGR and the SDA

Back in INTRSPY output in Figure 1 6 we saw that DOSMGR not only calls INT 21h AH=52h but also calls INT 21h AX=5D06h As noted in the appendix this undocumented function returns a pointer to the DOS Swappable Data Area SDA The SDA contains data structures in the DOS data segment It contains the current DOS state including the current Program Segment Prefix PSP the current Disk Transfer Area DTA the last DOS error code the three DOS stacks and so on

DOSMGR calls INT 21h AX=5D00h because it needs to mark the SDA as critical data Whereas DOSMGR has to get the right version control to navigate out the size of other DOS internal structures that must be examined It is easier to find out the size of the SDA An undocumented appendix INT 21h AX=5D0Ch provides a convenient pointer to the SDA plus a count of the number of bytes that a program must preserve when it issues a program initiated disk request while the InDOS flag is enabled

DOSMGR passes these values directly to the VMM VxDInstanceData function which correctly accepts a status byte and INDOS field and ALWAYS fields Given that the SDA itself is undocumented it is not surprising that the InDOS flag is not well documented Strangely enough the DDK documents these flags especially because VMM passes a pointer to them but it is not typical of the gross micro-scrutiny evident in the documentation for DOS and Windows The Windows documentation frequently reveals snippets of DOS knowledge that is essential to understand

DOSMGR and the InDOS Flag

As a good example consider the DOSMGR Get InDosPtr function documented in the Windows DDK According to the DDK VXDAPI this function returns the linear address of the MS DOS InDOS and ErrorMode flags unsupported but evident in DOSMGR see Figure 1 19 confirms that this is indeed exactly what the function does

Figure 1 19: Implementation of DOSMGR Get InDosPtr

```
    DOSMGR_Get_InDosPtr proc    near
017D7   mov eax,INDOS_PTR
017DC   retn
```

```
    DOSMGR Get_IndosPtr endp

; ;
; in initialization
05A7A   mov [ebp.Client_AX],3400h , set up client_reg struct for call
05A80   mov eax,21h               , call INT 21h AH 34h via Exec_Int
05A85   VMMCall Exec_Int          ,   (Get InDOS Flag Address)
05A88   movzx eax, [ebp Client_ES]
05A8F   shl eax,4                 ; ES <<= 4
05A92   movzx ebx, [ebp.Client_BX]  , mov with zero-extend
05A96   dec ebx                   , back up one to get ptr to CritErr
05A97   add eax,ebx               , create 32-bit linear address
05A99   mov INDOS_PTR,eax         , actually, both InDos and CritErr!
```

DOSMGR looks up the pointer returned from INT 21h AH 34h to get both the InDOS and CritErr flags into one convenient word-sized chunk, which can be used to test both InDos and CritErr in a single operation.

What's so shocking about that? INT 21h AH 34h and the InDOS flag are documented fully in the *MS DOS Programmer's Reference* that Microsoft issued at the time it released DOS 5.0.

Not only was the code shown in Listing 3.15 written long before that, but, more important, Microsoft's MS DOS documentation is still missing a critical detail. It fails to note that, at DOS 3.0 and later, the word returned by the InDos flag is the critical error flag. Microsoft probably doesn't document this because in some versions of DOS the critical error flag is located elsewhere; see the appendix. Yet Figure 3.4 shows that the documented DOSMGR Get_IndosPtr function relies on this undocumented aspect of DOS. As a result, as this book was going to press, we found that Microsoft's DOS programmer's reference *does* reflect reality, due to the fact that the critical error flag precedes the InDOS flag. In the words of Emily Litella: "Never mind."

SYSTEM.INI Settings and Undocumented DOS

Not only does Microsoft have programmer's documentation for Windows that relies on things that are still undocumented in MS DOS, but it also has *end user* documentation for Windows that relies on things that are part of undocumented DOS.

What Windows exposes of some way to DOS internals is clear even from a non-programmer's or end user's perspective. Because the Windows SYSTEM.INI configuration file can contain settings which relate to DOS functions, all structures that are or have recently been undocumented. The SYSINI.WRI file that comes with Windows describes these settings as does the *Windows Resource Kit* and *Windows for Workgroups Resource Kit* that Microsoft publishes.

```
[standard]
Int28Filter=0

[386Enh]
InDOSPol ing=No
Int28Critical=True
PSPIncrement=2
ReflectDosInt2A=False
UniqueDOSPSP=True
```

For example, the SYSINI.WRI file, which I remember is aimed at end users, not programmers, and which comes with the retail version of Windows, contains the following description of ReflectDosInt2A:

> ReflectDosInt2A=<Boolean>
> Default: False
> Purpose: Indicates whether Windows should consume or reflect DOS INT 2A signals. The default (False) causes Windows to consume these signals and therefore run more efficiently. Enable this setting (True) if you are running network software that relies on detecting INT 2A messages.

Microsoft's programmer's documentation even the latest programmer's reference for DOS 6.0 has no mention of INT 2Ah beyond the single vague sentence "Used by networks critical sections." We do appreciate believing that DOS programmers don't need to know about INT 2Ah. Microsoft feels it's need to say something about it to Windows end users.

In Windows Enhanced mode DOSMGR and associated VxDs check to see if INT 2Ah settings. The ReflectDOSInt2A setting, along with an undocumented Mode, DOSInt2A setting, is also checked in DOSMGR which contains an INT 2Ah handler. This handler, which like Windows Hook V86 Int Chain function, installs maps for INT 2A and sets appropriate functions provided by the Windows VMM. For example, the DOSMGR INT 2Ah handler sets Begin Critical Section to implement INT 2Ah AH=80h, End Critical Section to implement INT 2Ah AH=81h, and AH=82h, and Release and Block to implement INT 2Ah AH=84h. If ReflectDOSInt2A is set then DOSMGR also passes down "reflects" INT 2Ah calls to any INT 2Ah handlers that were installed before Windows.

KRNL386 Grows the SFT

Well, that's enough for DOSMGR. Popping back up to the INT 2Fh routine in Figure 1-6, we see that KRNL386.EXE in Windows kernel is finally running and it too calls our old friend, INT 21h function 52h to get a pointer to SysVars.

KRNL386 uses SysVars to get a pointer to the System File Table chain. Windows makes such heavy use of files that it would be handy to keep a lot of them open at once, so KRNL386 starts to increase the number of SFT entries by using undocumented DOS hacks that could have been Quarterdeck's QEMM or Helix Products's 386|UTILITIES. Actually, DOSMGR.EXE can grow the SFT, depending on the value of the VMM.INI system setting, SYSTEM.INI and can be disabled. SHARE is loaded.

KRNL386 executes the same set of SFT entries during its initialization. First, BootStrap. BootStrap is an internal KRNL386 function that calls another function, GrowSFTandMax, to do the dirty work. Chapter 4 of Matt Pietrek's book *Windows Internals: The Implementation of the Windows Operating Environment* discusses BootStrap and GrowSFTandMax. Pietrek also analyzing INT 21h AH=52h, GrowSFTandMax uses the DOS 3 protected Mode interface, DPMI, to get a protected mode selector to SysVars and to the SFT. After determining how many extra bytes it will create, GrowSFTandMax manipulates this number for 16-byte paragraphs and calls the Windows GlobalDosAlloc function to allocate the new SFT block of conventional memory. It then links the new SFT block into the end of the existing SFT chain. More SFT entries.

Where does Int 2Fh AX=1216h get the value of SFT entries to return? The appendix notes that an SFT entry is 38h bytes in DOS 3.0, 3Bh bytes in DOS 3.1, 3.2, and 3.3, and 3Ch bytes in DOS 4 and 5. But DOSMGR does not rely on this or any other knowledge. KRNL386 then calls undocumented DOS call yet another undocumented function, Get List of Lists. Now KRNL386 figures out the size of an SFT entry by getting the CON device and scanning the first 512 bytes of it for the string "CON" just as we saw DOSMGR doing earlier. Pietrek's *Windows Internals* book supplies pseudo-code for finding SysVars and explains Get List of Lists with the comment "Undocumented."

KRNL386 and the PSP

Finally, KRNL386 calls undocumented INT 21h AH=55h, the Create PSP function.

As explained in Chapter 7, every process in DOS has a PSP; the DOS EXEC function, INT 21h AH=4Bh, automatically calls INT 21h AH=55h to create a PSP. The PSP contains process information, the most important of which is the pointer to the PSP's file table. All open files in DOS are associated with a particular PSP. The PSP's paragraph address also acts as an identifier for the process. For example, DOS Memory Control Blocks are generally owned by some PSP. When the process exits, any MCBs marked with the block's PSP are freed — unless, of course, the process exits via the DOS TSR terminate and stay TSR, function

[illegible] DOS. Why is the Windows kernel creating PSPs? Because Windows isn't actually all that [illegible] DOS. Windows is a protected-mode DOS extender. Every process in Windows *also* has a PSP. When a process in Windows opens a file, its file handles are associated with, you guessed it, the PSP. When Windows program allocates memory via GlobalAlloc(), the block of memory is [illegible] (GMEM_SHARE) is associated with the PSP.

Now, PSPs [illegible] store a lot of information about the state of a Windows process. Because Windows isn't a multitasking DOS, [illegible] example, when running Windows program has its own current DTA and directory. Of course, I don't keep the program needs a DTA, as it resides in Windows' protected-mode memory space. There isn't room for any of this in the PSP, so Windows associates a data structure, the Task Database (TDB), for each copy of Windows that is PSP. Actually, a lot of undocumented structures are created. PSPs are called PDBs in the DOS source code, as in "Process Data Block." As both *Undocumented Windows* and *Windows Internals* explain, the TDB and PSP are linked together. You can think of the TDB as an extended PSP.

Every time KRNL386.EXE starts a new task, it creates a new set of data structures for the task, including a PSP. The kernel creates the DOS PSP and allocates it from conventional memory, where DOS can get at it. Even though Windows programs rarely access low DOS memory, an insignificant amount of low memory is set aside for each Windows program, not counting every block of otherwise precious memory. After all, even Windows programs sometimes use DOS, which needs to access a PSP to store the file handles, and PSPs must be accessible in low memory in order for DOS to find them. An important side point is that each PSP is specific to [illegible] associated with whatever task was running when the file was opened. [illegible] tasks and [illegible] PSPs.

Next, the kernel creates a Windows PSP. Windows applications, such as WinWord, Excel, Ami Pro, or any other Windows program, use kernel calls INT 21h functions exclusively. As explained in *Undocumented Windows*, these calls activate the internal kernel functions CreateTask() and InitPDB(). When these functions are called, a whole mess of INT 21h API [illegible] back and forth. Eventually, the first few parts would down to real-mode DOS. Windows is quite clever in KRNL386.EXE in that it doesn't switch to protected mode INT 21h API [illegible] Windows protected-mode code has a Windows interrupt-trapping program, such as WINSPY (Spector Windows from *Undocumented Windows*).

There are many more steps to Windows and the PSP that we don't have room to get into here. For example, as noted in the appendix entry for the PSP, see INT 21h function 26h. Windows [illegible] internal data in the PSP for its own purposes. The word at offset 42h contains a PDB flag. Undocumented 80h indicates that a program is running under Windows in an "old" DOS program. The preferred version, Windows program. Chapter 5 discusses the Windows PSP in more detail.

Undocumented DOS and the Utilities Wars

[illegible] look at Windows to look at other systems software for the PC. How much do disk compression, disk [illegible] caches, memory managers, DOS extenders, networks, and so forth rely on undocumented DOS calls?

DOS itself, the DOS [illegible] SUBST, JOIN, SHARE, PRINT, ASSIGN, and the [illegible] use undocumented DOS calls. You can check this out for yourself by running any of these programs under INTRSV (supplied with NDOS or 4DOS) using 1 2> trick, or [illegible] and INT 21h function 52h and [illegible] Get List of Lists) is [illegible] surprising. After all, it was for DOS's own internal use that function 52h was created in the first place.

[illegible] also [illegible] of [illegible] struggle with DOS. Every operating system must, by its very nature, have undocumented aspects. One of the key purposes of an operating system is to shield users and programmers from complexity, and the operating system should do that. Even vendor-documented calls, such as [illegible] system and even [illegible] hear on the PC marketplace, utilities are almost like applications. Some of the largest computer firms and some of the largest sales come from utilities. It

is not clear why they are so incredibly popular with consumers but the fact is that these utilities take a surprisingly important place in lists of top selling PC software. In a randomly selected issue of *PC Magazine* March 16 1993 the top five retail software packages included two of these QEMM 386 6.0 Quarterdeck and Stacker 3.0 Stac Electronics

The interesting thing is that all of these top selling PC utilities rely on undocumented DOS functions and data structures. Many of the programs that make up QEMM including BUFFERS.COM LOBS.COM FILES.COM FASTDRV.COM LOADHI.COM and MEMMAKE.EXE call INT 21h function 52h. In Stacker the programs LINDVOL.COM CHECKEM.STACKER.COM SWAPMAP.COM and SCREATE.EXE all use this most popular of undocumented DOS functions in order for example to find the DOS Disk Parameter Block DPB entry. Writing a competitive DOS utility without knowledge of undocumented DOS functions and data structures is impossible

Utilities are a major area of competition in the PC marketplace and yet competing in this market depends on having information about DOS that Microsoft refuses to disclose. Microsoft's refusal indicates a major problem. As new releases of MS DOS incorporate major features such as memory management and hard disk compression that once supported only third party vendors but which now provide services to the operating system itself third party utilities like QEMM and Stacker must increasingly compete with DOS itself. Microsoft has a very large lead as the producing software for this market and its control over the operating system documentation makes the playing field even more uneven

On the other hand lack of documentation hasn't yet kept anyone out of this market. As we've noted quite competitive. When Microsoft does document a new feature of DOS that it should programmers can pick up this information through reverse engineering or through sources such as this book. For all we know this is how many programmers at Microsoft first found out about DOS internals

The way that utilities use undocumented DOS as well as the way Windows uses it is a very important question. Is it right for Microsoft not only to make use of undocumented features in order to sell its PC utilities but also to prevent competitors from doing the same? Where the moral answer to this question lies is not clear. But the law sees the issue as we did with Windows we can point to a number of factors that favor some uses of undocumented DOS features over others. Microsoft's use of undocumented DOS features in its PC utilities is not a violation of the consent decree. To DOS 6.0 and beyond SMARTDRV.EXE is an entirely different DOS command line program in contrast to the older SMARTDRV.SYS which is a CONFIG.SYS loaded device driver from CONFIG.SYS. On the other hand the DOS 6.0 version of SMARTDRV.EXE also has a much more aggressive write behind cache which is crucial to data loss for users of inexperienced users

SmartDrive calls INT 21h function 52h but it seems like every program we look at uses this function so this is no longer very interesting. What is more significant is the fact that SmartDrive itself has an undocumented API for years Windows programmers know that Windows was able to grab memory back from SmartDrive temporarily. But how it did this and how non-Microsoft programs could perform the same trick as Windows was shrouded in mystery and confusion. Microsoft never documented this interface but after reverse engineering SmartDrive Scott Chappell revealed all in a January 1992 *Dr. Dobb's Journal* article "Untangling SmartDrive." Chappell's article showed

that programs could manipulate the SmartDrive cache using an IOCTL write (INT 21h AX=4403h) and read Lotus's SmartDrive using IOCTL read (INT 21h AX=4402h).

SmartDrive 4.0 and higher no longer use the IOCTL interface described by Chappell. SmartDrive now uses INT 2Fh AX=4A10h instead; this interface sometimes referred to as the BARF interface based on the 4A10h specification number is also supported with PC Cache 8.0. See the Appendix. DOS 6.0 comes with a SMARTMON utility that uses this interface to measure various aspects of SmartDrive's performance. Jeff Prosise's MS-DOS Q&A column in *Microsoft Systems Journal* (September 1992) mentions this interface briefly, but Microsoft has not officially documented it. In any case, *MSJ* showed only a few of the functions presented in SmartDrive 4.0, not how to shrink its cache temporarily. It appears that to shrink the SmartDrive cache, a program must pretend to be Windows by issuing the INT 2Fh AX=1605h and AX=1606h initialization and termination calls.

Undocumented DoubleSpace

The DoubleSpace file system interface that is provided by Microsoft in MS-DOS 6.0 is based on Vertisoft Systems' DoubleDisk. Its direct incorporation into DOS makes DoubleSpace formidable competition for third-party products such as the original disk compression utilities, Stac Electronics' Stacker. It is unfortunate that Microsoft gave Vertisoft no chance for DoubleDisk, offering instead the mere opportunity to market competing products to MS-DOS 6.0. In time, this rumor sheds an interesting light on Microsoft's decision to spend millions of dollars purchasing technology from smaller software vendors.

DoubleSpace's code is integrated into MS-DOS. In MS-DOS 6.0, a new system file, DBLSPACE.BIN, joins IO.SYS and MSDOS.SYS. IO.SYS reads DBLSPACE.BIN before processing CONFIG.SYS. DoubleSpace is transparent in a way that even the excellent Stacker program is not. In DOS 6.0, where Stacker pretends to, DBLSPACE.BIN thus shares as same preload hooks as DoubleSpace. In essence, DOS 6.0 has created a new "preload" API. That DoubleSpace calls upon it but DOS kernel level is where its legacy is unchanged from DOS 5.0 to 6.0. Even shown by the fact that the SYS and FORMAT commands now copy DBLSPACE.BIN alongside IO.SYS and MSDOS.SYS. DBLSPACE.BIN has two components: a disk space manager and a compress/decompress "engine" (see Chapter 8).

Not only has Microsoft made DoubleSpace incorporated into the DOS kernel as major element of MS-DOS 6.0, unlike Stacker, which Microsoft sells to DOS licensees such as IBM that DoubleSpace is *not* part of MS-DOS. In this clumsy arrangement, the retail DOS 6.0 with DoubleSpace is called the "Full Pack," and so IBM does not get DoubleSpace. So much for Microsoft's claim that DoubleSpace makes Stacker "integrated" into MS-DOS! When it suits Microsoft's purposes, it regards DoubleSpace as much separate from MS-DOS.

Microsoft has perhaps learned some important lessons because it is making available proper programmer documentation on DoubleSpace. The "DoubleSpace System API Specification" documents the INT 2Fh AX=4A11h interface provided by DoubleSpace. Early versions of this specification leave out functions 3 and 4 and say, "This API is reserved for SmartDrive." However, after complaints from developers, Microsoft decided to the final version of the specification to document these calls, since SmartDrive was not ready and so forced other developers to use DoubleSpace. These functions are useful for non-Microsoft disk caches.

Microsoft's "DoubleSpace Compressed Volume File Overview" describes the actual disk format of CVFs, see Chapter 8. The "Microsoft Real-time Compression Interface (MRCI) Specification" documents a device interface, MRCI protected-mode, which uses INT 2Fh AX=4A12. The MRCI specification also documents INT 4Bh AX=8001h for compression hardware.

The entire DoubleSpace MRCI documentation is readily available on CompuServe, on the Microsoft Developer Network CD-ROM, and in the MS-DOS 6.0 version of the *MS-DOS Programmer's Reference*. It is worth contrasting the abundance of information Microsoft provides for DoubleSpace with the difficulty of locating programmer's documentation for Stacker.

The MRCI documentation is particularly interesting because, far from destroying a market, MRCI might create some interesting new possibilities for third party disk compression vendors. MRCI defines an interface between compression clients and compression servers. For example, DoubleSpace's disk space manager is a client and its compress/decompress engine is a server. With the MRCI specification, third party vendors can create new MRCI clients such as disk defraggers, disk caches, backup programs, and network transports that know about DoubleSpace. These vendors could also create new MRCI hosts such as disk compression hardware similar to Stac Electronics' business before Stacker.

Still, not quite everything about DoubleSpace is documented, and the few remaining undocumented aspects of DoubleSpace appear to be at the center of Microsoft's legal battles with Stac Electronics. Stac originally sued Microsoft for patent infringement. Stac holds the disk compression patents. Stac may have passed the source legal opposition for Microsoft, returned empty-handed, and charged Stac with trade secrets violations and asked for an injunction to block shipments of Stacker 3.1 (*InfoWorld*, August 16, 1993). Such an injunction could bankrupt Stac out of business.

In MS-DOS 6.0, DBLSPACE.SYS MOVEs over INT 2Fh AX=4A11h BX=1111h and BX=1112h to get DBLSPACE.BIN to move itself. As noted earlier, INT 2Fh AX=4A11h is used by the documented DoubleSpace API. However, subfunctions 1111h and 1112h are not documented. Because of its small size (339 bytes), it is trivial to disassemble DBLSPACE.SYS and with Microsoft's DEBUG. Source code search: DBLSPACE.SYS calls undocumented DoubleSpace function FFEEh to get DBLSPACE.BIN's relocation size and it passes FFEEh to tell DBLSPACE.BIN to move itself to its new position in memory. See the partial listing on disk.

In MS-DOS 6.0, IO.SYS's processing of DBLSPACE.BIN, which in turn drivers in CONFIG.SYS, involves another undocumented feature. Microsoft added hooks to IO.SYS to preload DBLSPACE.BIN so that it can control over MS-DOS. By using itself, DBLSPACE.BIN under MS-DOS 6.0 Stacker is designed to get itself preloaded by IO.SYS. However, simply running Stacker's DBLSPACE.BIN without first installing IO.SYS will. Source reveals that there is a check at offset A2h. DBLSPACE.BIN contains a 20-byte signature at offset 12h and a function pointer at offset 4. If there is also a check for MRCI information structures. After using INT 21h AX=4B05h to load DBLSPACE.BIN, IO.SYS checks the signature at offset 12h and calls a preload entry point at offset 4. For example, function BX=4 queries the preload program's size, which the preload program (such as DBLSPACE.BIN) must return in AX. IO.SYS calls subfunction 6 to tell the preload program to relocate itself to the top of memory.

```
mov  bx, 4          ; Query Size
call dword ptr cs:[PRELOAD_FUNC]
mov  bx, word ptr, cs:[MEMORY_END]
sub  bx, ax
cmp  bx, word ptr cs:[MEMORY_BASE]
jb   elsewhere
sub  word ptr cs:[MEMORY_END], ax
word es, word ptr cs:[MEMORY_END]
mov  bx, 6          ; Relocate
call dword ptr cs:[PRELOAD_FUNC]
mov  word ptr cs:[MEMORY_BASE], ax
```

IO.SYS appears to use preload subfunction 2 to tell DBLSPACE.BIN to mount drives. Of course, IO.SYS also uses the documented INT 2Fh AX=4A11h interface to communicate with DBLSPACE.BIN. I do MS-DOS 6.0 Stacker must implement the same APIs as DBLSPACE.BIN so that IO.SYS will preload Stacker as though it were DoubleSpace. Interesting. Now, DOS comes bundled with Stacker, which is widely held to be superior to DoubleSpace, and uses the same preload API to load a file called either STACKER.BIN or DBLSPACE.BIN.

[illegible] to implementing some important undocumented interfaces DoubleSpace itself relies, to a surprising degree, on undocumented DOS calls given its competition with Stacker and SuperStor this is logical. Of course, as noted above, Stacker also uses undocumented DOS and presumably SuperStor does too. And as mentioned, Stac's programmers' documentation for Stacker is nowhere as [illegible] as Microsoft's documentation for DoubleSpace. But isn't there a difference between a third-party vendor using undocumented DOS calls and Microsoft using them? And isn't there a difference between a third-party vendor trying to document its programming interfaces and Microsoft doing so? Lawyers have on occasion argued that even a trade practice is legal in the hands of a small company, the same practice can be illegal in the hands of a monopolist.

Disassembling DBLSPACE.BIN with Sourcer shows that DoubleSpace calls INT 21h function 52h (Get List of Lists/SysVars) to get a pointer to the DPB chain and offset 16h to get to the CDS table. DoubleSpace then makes a call to the undocumented IOSYSMGR VxD in Windows.

If DOS=HIGH with the SPACE.BIN device parameter, part of DOS can be put in high memory area (HMA) if [illegible] extended memory. How does it do that? Programmers have frequently noted that there must be parts of the HMA that DOS doesn't use; for example, the BUFFERS= setting is small. How does DBLSPACE.BIN get at these areas? It uses two undocumented calls: INT 2Fh AX=4A01h (Query Free HMA Space) and INT 2Fh AX=4A02h (Allocate HMA Space); see this appendix. These functions were [illegible] with sample code in *Microsoft Systems Journal* March 1993 in Jeff Prosise's "MS-DOS Q&A" column. It's a depressing comment on the state of DOS that the ability to access an extra 0.7K is considered a useful feature, so this is another interface that Microsoft should formally document.

Undocumented EMM386.EXE

Compaq appears to have originally written Microsoft's memory manager EMM386. EMM386 [illegible] protected-mode memory managers such as QEMM and 386Max.

EMM386 uses [illegible] knowledge of Intel 386 protected mode and virtual 8086 (V86) mode [illegible] knowledge of undocumented DOS. This includes undocumented aspects of the Intel architecture, such as the 286- and 386-LOADALL instructions, which EMM386.EXE special cases in its invalid-opcode handler. For more on LOADALL, see the superb article by Robert Collins, "The LOADALL Instruction," which appeared in *PC Techniques*, October 1991.

EMM386.EXE is a complex Windows virtual device driver (VxD). Whatever normally think of as the DOS driver, there is just the tiniest stub in a conventional VxD. The start of the file looks like a normal DOS executable. Microsoft Knowledge Base article "Installing a TSR in a VxD" (Q74516) describes how a simple [illegible] EMM386.EXE and IFSHLP.SYS use the same format.

The VxD portion of EMM386 is [illegible] Disassembling with Sourcer shows that in addition to [illegible] DOS Set Upper Memory Link function (INT 21h AX=5803h) and hooking VxD [illegible] such as VMM(Init_Complete), PageOut, V86MMGR_Int_Reflect, and DOSMGR_Instance_Device, the LoadHi VxD [illegible] patches in V86MMGR. This patching is evident when you do a strings listing of EMM386.EXE or the LoadHi device such as 386MAX.VXD.

[illegible] LoadHi device is a clever piece of [illegible] and is an example of how a DOS-provided ability such as EMM386 gives [illegible] Windows. According to the DDK, one of the functions VMM provides is Hook_Device_Service. This function allows an VxD to intercept any function that VMM or another VxD provides. This ability is typical of the far-reaching capabilities that VMM functions offer. Hook_Device_Service takes a function number; for example, Hook_Device_Service itself is function 0x100906, and it returns to the new intercepting function. Hook_Device_Service returns the *previous* handler's address in a way which DDK doesn't explain very well. The intercepting function typically saves the pointer to the previous handler to "chain." This is how LoadHi hooks the DOSMGR_Instance_Device call, for example. So far, so good.

Now, a VxD that wishes to *patch* VMM and VxD functions rather than hook Device Services Hook Device Service. The VxD passes in an invalid function pointer of 1. It gets back the previous handler then calls Hook Device Service a second time with the function pointer to the previous handler. Nothing has been changed except the VxD now has the address of the code it wishes to patch. Generally the VxD compares some bytes at that address to say that the code matches what it expects then it attacks its own code. The second portion of EMM386 uses this technique to patch the V86MMGR Set Mapping Interval V86MMGR Get LIN XMS functions. Under certain circumstances the WINA20.386 VxD included with DOS uses the same Hook Device Service trick as EMM386 to patch the V86MMGR VxD in Windows 3.0.

That an MS DOS utility patches Windows is the most ironic thing one can imagine of the special relationship between these two products. Back in memory serving 386Max and QEMM also included LoadHi so here Microsoft shares a bed with its own competitors. Novell's version of EMM386 in DR DOS 5.0 also includes a LoadHi VxD. But Novell's LoadHi received the Windows 3.1 version of the LoadHi code out of the related Global Memory Paging specification and so they had to pay DRI their source $. Meanwhile most other memory managers and Windows had no problem getting these materials. The same thing seems to have happened with the XMS 3.0 specification. This is a good example of how the problem with Microsoft's undocumented interfaces isn't *that* they're undocumented — which the company gives out to its customer competitors on a case by case basis is [illegible].

This seems to be the case with EMM386. For example, EMM386 cooperates with V86MMGR using an undocumented interface sometimes called the Windows 386 Paging Support specification and sometimes called the Global EMM Import specification. Why Microsoft has not documented this specification [illegible] appear to have shared this information with some other memory management vendors. It's hard to imagine anyone else who would want this information anyway. One tech reviewer writes: "I believe it was put there to help them take over from a memory manager." Sheesh!

In addition, EMM386 provides a small API through INT 67h. MAPMEM.ASM, INTR.ASM on the disk accompanying this book.

With all the undocumented things EMM386 does, remember that here Microsoft has at least some sort of sharing arrangement with the other memory management vendors. So perhaps it's a political problem rather than a technical problem. Microsoft's undocumented EMM386 services give it a competitive advantage. EMM386 is [illegible] because it uses 386Max or QEMM using fewer tricks or more. EMM386's competitive advantage comes directly from its undocumented interfaces to Windows. Microsoft's statement that the Microsoft Windows Software Development Kit contains a fairly clear statement of the advantages *and disadvantages* of EMM386 compared to other third-party memory managers.

EMM386 is discussed in more detail in Chapter 5 *DOS Internals*.

Microsoft Anti Virus

Starting with MS DOS v5.0, Microsoft began including, borrowed third-party utilities into the operating system. DOS v5.0 included the MIRROR, FORMAT, and UNDELETE utilities from Central Point Software, the makers of PC Tools, which competes with the Norton Utilities. Gee, Sorry. DOS 6.0 incorporates many of these from Central Point, plus Stacker's DBLSPACE, which is similar to SpeedDisk in the Norton Utilities. The Central Point utilities in DOS 6.0 and later versions Windows except tables and DLLs apparently a Central Point succeeded in exchanging technology tools to Microsoft was a success from Microsoft allowing Central Point to see the look and feel of the DOSSHELL. Newsbytes, June 12, 1991. Some deal!

We could spend days just looking at the different Central Point utilities included with MS DOS v6.0. The inclusion in DOS of software that requires Windows itself interesting, but it's too soon to

etc.) these utilities. Microsoft Anti-Virus (MSAV). In a useful roundup of the utilities in MS-DOS 6.0, *PC Magazine* (April 13, 1993) noted that the inclusion of MSAV in DOS 6.0 is "a serious blow to the stand-alone anti-virus software market." It is unclear how necessary all this anti-virus software really is, given the extremely low incidence of verified virus sightings, but certainly this is a very active part of the PC software market.

MWAV.EXE, from Central Point's Anti-Virus for Windows, relies on many dynamic link libraries, as does MWAVMGR.DLL (VSR manager). MWAVSCAN.DLL (virus scanning support), MWAVVSI.DLL (obsolete disk I/O), MWAVDLG.DLL (dialogs), and so on. That DOS 6.0 now uses so many Windows DLLs raises an intriguing question: Are these DLLs now part of MS-DOS? The names of the functions these DLLs export are parsable using utilities such as Microsoft's DUMPBIN and Borland's TDUMP. Locating functions in DLLs was discussed in agonizing detail in *Undocumented Windows*. For example, MWAVSCAN.DLL exports many named functions, including CPAV_ScanFileForViruses, CPAV_ScanBootForViruses, CPAV_KillFileVirus, and CPAV_KillBootVirus. Are these now part of DOS? Should they be documented? Who the heck knows.

The good news is that most of these Windows executables or DLLs seem to use undocumented Windows calls. Naturally, MWAVSCAN does not work at low level, still making heavy use of DPMI functions (undocumented SetSelectorBase and SetSelectorLimit functions), and several DOS calls (undocumented MWAVMGR.DLL calls) — at least contains calls to INT 21h AX=6282h and AX=6284h. A number of INT 2Fh/REXT class functions are part of the PC-DOS interface. Given the evil INT 2Fh/REXT, Microsoft and Central Point — or at least the cooperation of so many former Central Point employees — DOS 6.0 should this API not be considered part of MS-DOS?

One of the Windows DLLs is MWAVABSI.DLL, a collection of functions for absolute disk I/O. (See AIO_GetDDHeader, AIO_GetFirstDevice, AIO_GetNextDevice, and AIO_EnumNextDevice.) Information provided by MWAVABSI.DLL's AIO_GetDDHeader lists — once the Windows DOS3CALL function is called to do the INT 21h — the pertinent DOS internal data structures. Further evidence of intent were needed that Microsoft needs to document INT 2Fh/AH=52h, but certainly at least there is no question of insider knowledge. Note that the structures listed also correspond to Ralf Brown's Interrupt List and general PC folklore, *but not* to the MS-DOS source code, which lacks these data structures. SysInitVars.

Another function exported from MWAVABSI.DLL is Init130, also calls INT 21h AH=52h and creates a protected-mode pointer to the SysInitVars SFT. Figure 1-20 shows the code. The code converts the real-mode SFT segment to a protected-mode selector using DPMI function 0002h, which creates a new protected-mode selector that is an alias for the real-mode segment. While DPMI itself is hardly undocumented, the DPMI specifications could be upgraded at no charge to one Intel. Microsoft barely documents the presence of DPMI even in the Windows SDK. Windows 3.1's Windows SDK contains a total of four pages on both DOS extender and DPMI. "Windows Applications with MS-DOS Functions" (*Programmer's Reference, Volume 1: Overview*, Chapter 21) is this skimpy chapter, which also incorrectly claims that Windows supports version 1.0 of DPMI. (It's version 0.9.) DPMI functions that Microsoft approves for use by Windows applications (function 0002h is not on the list. Microsoft's rendition of the golden rule would appear to be "Do as I say, not as I do."

Figure 1-20: MWAVABSI.DLL Creates a Protected-Mode Pointer to the SFT

```
7 087A   mov ah,52h                    ; most popular undoc function
7 087C   call far ptr DOS3CALL         ; call INT 21h
7 0881   mov ax, es:[bx+4]             ; sysvars[4]=SFT chain offset
7 0885   mov word ptr SFT_PTR, ax      ; save offset
7 0888   mov bx, es:[bx+6]             ; sysvars[6]  > SFT chain segment
7 088C   mov ax, 2                     ; DPMI Segment to Descriptor
7 088F   int 31h                       ;    Input BX=real mode segment
7 0891   mov word ptr SFT_PTR+2, ax    ;    output AX=pmode selector
```

MWAV ARSLDLL makes extensive use of this protected mode pointer to the SFT chain. For example, the exported MOUNTSTATESFT function (function 0 of course) uses SFT_PTR.

MWAV ARSLDLL raises yet again the old question: Does Microsoft use undocumented functions in products that compete with third parties' products? *PC Magazine*'s statement about the blow MSAV was going to deal to the anti-virus software market and whether Microsoft needs to document the API exported from ARSLDLL is incorporated in MS-DOS 6.0. In any case MWAV ARSLDLL constitutes further proof that undocumented functions are useful and that it is crazy for Microsoft not to document INT 21h AH=52h. Crazy or monopolistic.

Still isn't it okay for Microsoft to use undocumented calls within the services that ship as part of MS-DOS? In the case of SETVARS, PRINT, SUBST, and so on, the answer is obviously that it is okay. Every operating system must have undocumented interfaces. If every interface were documented, then the operating system would not be doing its job of shielding developers from complexity.

But what about utilities bundled with the operating system such as Microsoft Anti-Virus or DoubleSpace that compete with already existing third party products. Here the answer is less clear. *PC Magazine*, September 14, 1993 has complained that "in adding these utilities, Microsoft has clouded the definition of exactly what a operating system should be." Many would disagree with this statement. What is separable from the operating system? The very existence of third party products would seem to be the key test. Consumers have demonstrated a desire to purchase in large numbers utilities that compete with software that comes bundled free as part of MS-DOS. Even the Microsoft CD-ROM Extensions (MSCDEX) have competition in a product from Corel Software. Where does the operating system stop and the third party utilities/after market begin? At what point does Microsoft's use of undocumented DOS calls cease to be operating system internals and turn into an advantage over competitors? At what point is this advantage unfair?

The answers seem to be clear when we get to products such as Word for Windows, Windows for Workgroups and other Microsoft products that are sold separately from MS-DOS. However, here there isn't a simple answer. If Microsoft bundles Windows with MS-DOS (as it would with the upcoming "Chicago" operating system) does the problem go away? Is bundling a good solution to the problem of tying? Perhaps. On the other hand, the continued existence of products such as DesqView testifies to the fact that it is not necessary for consumers to buy pieces of the operating system separately. Software is the aftermarket for automobile spare parts.

In the end, I am forced to declare today Windows and DOS are separate. Windows relies on INT 21h function 52h, as well as the CDS, the SFT, and other undocumented DOS calls and structures. Microsoft's failure to document these or to provide documented equivalents is monopolization with no benefit to consumers and with harm to third party developers.

No Problem?

The problems with undocumented DOS are that 1. some of these functions and data structures are absolutely crucial to DOS programming, 2. Microsoft uses these functions and data structures in its own software that competes with third party utilities, and 3. programmers have repeatedly and vociferously requested that Microsoft document these structures. While Microsoft did finally document a number of previously undocumented DOS functions when they released DOS 5.0, there are still many (INT 21h AH=52h in particular) for which Microsoft denies there is any problem.

Press secretary *ahoy*. Microsoft's position has changed over time (things do occasionally). Microsoft representatives will deny ever that undocumented DOS or Windows or OS/2 calls even exist.

But usually what Microsoft denies is that Microsoft applications use or derive any advantage from these calls. For years, Microsoft has claimed that between its operating systems and applications groups there is "separation of church and state" or, using a term from the insider trading scandals of the 1980s, a "Chinese Wall."

Stephen Manes and Paul Andrews discuss the Chinese Wall issue at length in their fine biography of Bill Gates, *Gates: How Microsoft's Mogul Reinvented an Industry—and Made Himself the Richest Man in America* (1993). There have been other biographies of Gates and histories of Microsoft, but this is the best-researched one. It's a superb book, not a *People* magazine style report on Gates' life who cares—but rather an in-depth study on how Microsoft does business. On the question of the supposed Chinese Wall between Microsoft's two businesses, Manes and Andrews report:

> As early as 1983, Microsoft executive VP Steve Ballmer had stated that "We have structured it so that there is a very clear separation between our operating systems business and our applications software. It's like the separation of church and state. And if you don't play straight, you can't expect to get the business." But except for Ballmer's favorite pronouncement, "get the message," it was hard to swallow. There had been no formal division between systems and apps until mid-1984.

Interestingly, a lot of the fears about Microsoft's applications conflicting with Microsoft's role as an operating systems vendor were present at the time of OS/2.

> In fact, Brad Silverberg, then OS/2 development director, told *InfoWorld* columnist (now *PC Week*) Peter Coffee that Microsoft reported that "several developers I've talked to recently believe that Microsoft has an unfair advantage in developing applications that will run under OS/2." Coffee's unidentified sources were not alone.
>
> Microsoft's Adrian King insisted that "There are no undocumented interfaces in OS/2." Coffee countered with the assertion that "[t]here are undocumented interfaces in OS/2 for the operating system's enhancement." Finally King admitted what was patently obvious. There were no Chinese walls that truly separated the applications and systems sides of the company.

Subsequent to Microsoft's denial that there were any undocumented interfaces in the first version of OS/2, a DosPTrace function most of us knew existed (codes for the equivalent DOS function, DebugActive, were documented; see "Stalking Ol' Faults," *PC Tech Journal*, February 1990). A powerful and undocumented function never dies. It is amusing to note that Microsoft finally documented DosPTrace—to create the important Windows WinDebug hooks—in the same manual in which Microsoft refuses to document, supposedly because the function is "going away," which doesn't in fact appear to be happening.

Relating to the supposed separation of Microsoft's applications from its operating systems and the "ugly word" in that separation, Manes's biography has a particularly revealing and balanced summary:

> In later years the Chinese Wall separation would be roundly derided and the "ugly word" embraced, the cleaving opposed. "There's a kind of a wall, but there's not a watertight wall where [Excel or Windows developers] can't see what it looks like. And [Microsoft executive Mark Ryland] was going to scream at me [for] friendlier to the guy down the hall than the guy in Redmond." If a Microsoft apps developer walked down the hall to a Windows developer and asked for a favor to make Excel run better, was that [violation of] antitrust?
>
> Besides, in the eyes of the applications world of Microsoft, just asking for something didn't mean you'd get it. Windows developer Steve Wood [...] kept begging the languages group to give its C compiler some [...] tools he and others desperately missing for Windows developers [...] at home and out. The languages guys didn't care, and it was years before his wish list was implemented. (pp. 349–350)

To anyone who has ever dealt with both the Microsoft languages and operating systems groups, this last part rings especially true. There appears to be an intense rivalry, and something approaching intense dislike, between these two groups at Microsoft.

Unfortunately, though, the Chinese Wall didn't hold much water because, as was known in *Undocumented Windows*, whatever separation did exist was completely informal and obviously not a matter of great importance to Microsoft. Why else, somehow Microsoft applications such as Excel and Word for Windows could be running undocumented Windows functions, even though Miss Maples, for example, claimed *InfoWorld* December 30, 1992, that the biggest secret would be if we were using secretly undocumented things and we very consciously avoid that." It is important to stress that having its applications use undocumented functions was not a major or even a minor part of Microsoft's competitive strategy, but nonetheless the company's management seems to have some deliberate policy *not* using these functions as was shown to be totally wrong.

Having failed to deny completely that undocumented functions exist or that Microsoft uses them, Microsoft's next defense was that since the functions exist and since Microsoft applications use them, but the functions were for system purposes, far from giving Microsoft a competitive advantage, this argument goes, calling these functions actually puts it at a disadvantage. Oh yes, and war is peace. We have always been at war with Oceania.

This approach came out during the major press tour created with *Undocumented Windows*. See, for example, "Microsoft Reveals Bad Ones, Hows About Windows," *Wall Street Journal*, September 1, 1992. Microsoft and its fanatically aggressive public relations firm, Waggener Edstrom, issued several press releases on the topic. Microsoft Statement on the Subject of Undocumented APIs, August 31, 1992. "Questions and Answers About Documented and Undocumented APIs," undated, and "Undocumented Functions," undated, which put forward this idea that using undocumented functions puts Microsoft at a *disadvantage*.

Take, for example, the undocumented Windows function GetTaskQueue(), which *Undocumented Windows* shows that Microsoft QuickC for Windows uses, as do the PC marketplace compilers are applications. Microsoft's undocumented function's status is given as "No equivalent, but useless." Elsewhere the Microsoft statement said that using GetTaskQueue() "is a way of shooting yourself in the foot, but the same thing can be said of dozens of perfectly legal functions." The fact that Microsoft was caught calling

While some of the undocumented functions that Microsoft applications call are useless, representing remnants left from older versions of Windows, this definitely was not the case with GetTaskQueue(). Disassembly of QCWIN.EXE shows that the programmers have used an undocumented function to determine if there is a message pending for the current program, such as when the QCWIN integrated development environment is loading. This is QCWIN needing to know whether the user's program has executed past the section of its startup code that provides for the application to establish a task queue. If an application does not have a task queue, sending it messages can cause bizarre behavior. QCWIN contains the following code:

```
if (GetTaskQueue(hTask) != 0)        // if there's a queue
    PostAppMessage(hTask, ...);      // send a message
DirectedYield(hTask),                // either way, do DirectedYield
```

Microsoft claims that the function SetMessageQueue() is a documented alternative to GetTaskQueue(), but whoever wrote that probably just looked up the word "queue" in the index. SetMessageQueue() simply sets the size of a message queue; it says nothing about QCWIN's problem, which is to ensure that a task has a queue. But then one wonders why undocumented functions such as GetTaskQueue() are undocumented, one QCWIN uses the undocumented way.

There are other examples besides GetTaskQueue(), but this is supposed to be a book about DOS, not Windows. Things are hard to keep them separate these days. So we'll move on. Microsoft's "we call these functions as the neighborhood watch program's at a disadvantage" argument, the playing field argument basically isn't very effective.

We expect Microsoft's next defense to be that sure, Microsoft uses these functions, but only because they are useful, but that *everyone* uses them. In fact, one of Microsoft's statements to the media is

"Behind Windows controversy" notes that "MS-DOS has a number of undocumented APIs that are well-known, well-understood and used by ISVs" (independent software vendors). Well, okay, but then why not document them?

DOS Documented

We had ceased the subject of *why* Microsoft leaves crucial pieces of DOS functionality undocumented in a minute, but it's important to note first that the company has to its credit finally documented some of the obscure, well-known and well-understood previously undocumented functions.

In November of 1991, Microsoft Press issued the *Microsoft MS-DOS Programmer's Reference*, which includes the new INT 21h and INT 2Fh functions in MS-DOS 5.0. This book came out after the publication of the first edition of *Undocumented DOS*, and the Microsoft Press advertising headline for the programmer's reference was "DOS Documented." Microsoft released a nearly identical version for MS-DOS 6.0 in the summer of 1993.

Indeed, the programmer's reference did document some previously undocumented calls. Most notably, Microsoft blessed the following previously undocumented INT 21h functions:

- Function 1Fh: Get Default DPB
- Function 32h: Get DPB
- Function 34h: Get InDOS Flag Address
- Function 4B01h: Load Program
- Function 50h: Set PSP Address
- Function 51h: Get PSP Address
- Function 5D06h: Get Extended Error

However, documentation for these old functions is unfortunately far from complete. One gets the sense that to some extent the point of this exercise for Microsoft was simply to claim that these functions are now documented. Let's look at the documentation for the previously undocumented INT 21h functions to see what problems:

- Functions 1Fh, 32h: The programmer's reference claims that these functions are only for DOS 4 and higher. In fact, these functions are present all the way back to DOS 2.0. This is an important piece of information because a large number of DOS 3.x installations are still in use, and most PC disk utilities which call function 32h must be able to run on these machines. The DPB structure provided is only accurate for DOS 5.0 and higher. Basically, if you believe Microsoft's documentation, PC disk utilities can only be written for DOS 5.0 and higher, which we know not to be the case.
- Function 34h: The documentation doesn't mention the critical error flag located in the byte immediately before the InDOS flag. As we saw earlier, the Windows DOSMGR relies on being able to decrement the critical error flag from function 34h to get both the InDOS flag and critical error flag into a single word.
- Function 4B01h: The documentation for the LOAD structure incorrectly reverses the order of the initSP and initSSSP fields. Some errors are, of course, unavoidable, but the identical error had appeared earlier in the book *Developing Applications Using DOS* by three IBMers: Ken Christopher, Barry Feigenbaum and Shon Saliga (1990). Presumably, Microsoft used this book as one of its source material for the MS-DOS 5.0 programmer's reference. The MS-DOS 6.0 programmer's reference does correct this error. For a full explanation of function 4B01h, see Tom Paterson's "The MS-DOS Debugger Interface" in the first edition of *Undocumented DOS*.
- Function 5D0Ah: This function is documented only for DOS 4.0 and higher. In fact, it is present in 3.x and higher. Furthermore, because the manual does not mention the other AH=5Dh

functions the ERROR structure has held out what best battle-scarred readers. According to the programmer's reference, each DOS "identifies the computer operations that occur on remote computers." How remote operations. Without documenting the Novell NetWare Server Function Call and its own DOS primitive, but states that see the appendix of the state of affairs little worse. Lots are DOS documented ways such as DOS's USER ID field discussed earlier in this chapter. Under Windows Enhanced mode, the first thing the VMM does when a DOS program executes is hook up INT 21h AX=1658h. That's seven enough to indicate that Microsoft's documentation of the Microsoft Press MS-DOS 5.0 programmer's reference, associated with the ERROR structure goes on, DOS, when it stated goes DOS, DX. Lots at least was fixed in the MS-DOS 6.0 programmer's reference.

Well, suggests on to such chosen, and they not to have these functions made through the official INT 21h fold.

In addition, Microsoft documented INT 28h, MS-DOS Idle Handler, and a number of INT 2Fh calls:

- Function 0110h, Get Character Device Chain, the first edition of *Undocumented DOS* incorrectly identified this call as PRINT.COM Check Device and Output Device.
- Function 0800h, Get ASSIGN.COM Installed State
- Function 1000h, Get SHARE.EXE Installed State
- Function 1100h, Get Network Installed State
- Function 1400h, Get NLSFUNC.EXE Installed State
- Function 1400h, Get ANSI.SYS Installed State
- Function 4A00h, Get KEYB.COM Version Number
- Function 4A01h, Set KEYB.COM Active Code Page
- Function 4A02h, Set KEYB.COM Hotkey Flag
- Function 8000h, Get IBMBIO.COM/IBMDOS.COM Installed State
- Function 8700h, Get APPEND.EXE Installed State
- Function 8702h, Get APPEND.EXE Version
- Function 8704h, Get APPEND.EXE Data Segment Address

Two interesting points emerge from this. First, Microsoft documented the first seven INT 21h functions, 34h–40h, 50h, and 51h, according to the documentation, have existed as far back as DOS 2.0. I suspect, as I think others have, I suspect that they really existed. Programs use undocumented DOS calls, and useful ones at that.

Second, which I find very interesting, that Microsoft never removed. Rather, in each big change, Microsoft has added functions, but never removed them. Of course, we only have the 100 percent of Intel's 80x86 instruction space to see, which is proved undocumented functions because they're not very much easier. We'll deal with this subject again shortly.

The *MS-DOS Programmer's Reference* left out of the section undocumented DOS structures their orphaned sons. Of course, a curious fourth-grader can't find out the size of the SDA structure nor does it say where, only that it's DOS.SYS. The MCB structure is documented, under the name ARENA, but now not the location of the MCB. Version never mentioned. Several important fields in the PSP are still undocumented. As noted earlier, only one INT 21h API is documented, even though. The network redirector is not mentioned, and the only undocumented function was INT 2Fh AX=1100h, the entire INT 2Fh interface is absent. Instead, there's a single cryptic reference to "Network Control Services." Aside from documenting some of the new functions in DOS 5.0, the programmer's reference didn't add very much to the state of DOS knowledge. The DOS 6.0 version at least includes the DoubleSpace API and MRCI documentation, so we already have the book merely pat Microsoft's grudging and belated approval on a small, already well-known part of its

[illegible] Borland put it at the top of the seven independent *Microsoft Systems Journal* January–February 1992: "We know that Microsoft seems to have finally realized that a number of 'undocumented' functions were in fact documented everywhere but the MS-DOS technical reference."

Why Leave Functionality Undocumented?

Why doesn't Microsoft do a better job with the DOS programmer's reference? Why, for example, given the importance of certain important DOS programming hooks, are they not documented (INT 21h functions 52 and 5D, the List of Lists)? Why are they still backing away from the network redirector specification? Why aren't the low-level functions (INT 2Ah critical section stuff)?

In some cases, Microsoft's reasons aren't really very different from the reasons other vendors document only about 50% of everything that a person would ever need to know. The difference is that Microsoft now occupies such a central role in the software industry that when Microsoft fails to document important, obscure areas, it affects many more programmers much more deeply than when [illegible] documents 50% of its system essentials in INT 21h.

Of course, not all undocumentation is simply a resource allocation problem. It is not easy finding qualified technical writers, and those who are qualified would probably rather write code. Any company that's had difficulty finding good technical writers can sympathize with Microsoft's problems. I've suggested Microsoft when a document is good people to write excellent documentation, such as the Microsoft Developer Network (MSDN) CD-ROM. If you have the MSDN CD-ROM, look at, in particular, the excellent articles by David Long.

[illegible] problem is not the main reason for inadequate documentation. It puts the emphasis on the wrong part of the equation. In a new light, Microsoft's practices have on several occasions [illegible] the opportunity to set all the key software standards. Microsoft wants to become the [illegible] in many areas such as keyboards, copiers, fax, and television. There's no reason why it shouldn't succeed in these. However, if Microsoft wants to set every standard and control every API, it needs to make sure that it has the resources to maintain those standards and properly document its APIs.

The problem with Microsoft is simply that its eyes are bigger than its stomach. It works on too many projects at once and does not have adequate resources to document. The problem is, of course, not lack of resources but lack of perspective. Microsoft's policy of deliberately understaffing projects [illegible] "Something has to give," and documentation is a frequent casualty. Especially when the existing documentation will satisfy, say, 85% of the users it [illegible] to write the rest of it necessary to supply what is needed by the remaining 15%. There are [illegible] documentation just as there are [illegible] fixes.

Yet, I don't mean to paint a bad picture for the rest of the industry. If Microsoft's eyes are bigger than its stomach, [illegible] Microsoft takes on projects for which it can do only an adequate job, one technical reviewer [illegible] Microsoft has a talent for providing 85% solutions—this situation opens up many niche opportunities for other companies. Microsoft's current [illegible] memory management market is a good example. [illegible] vendors believed that the introduction of DOS 5.0 would shortly lead to [illegible] Instead, these companies [illegible] vendors such as Qualitas and Quarterdeck. Instead [illegible] Microsoft's [illegible] Even [illegible] with DOS 6.0, the market for memory [illegible] is very healthy. Apparently, [illegible] knows how to "look a gift horse in the mouth." [illegible] Quarterdeck suggests, DOS 5.0 legitimized the idea of 386 memory managers but [illegible] itself [illegible] its memory manager. Companies such as Qualitas and Quarterdeck were able to exploit this contradiction. This book is itself a good example of how Microsoft's endless approvals on quick solutions can create opportunities for others.

Another reason is that some of the things like the network redirector that Microsoft ought to [illegible] the code and document are more valuable to it in their undocumented "magic" state. Documentation is [illegible] documentation. [illegible] an important undocumented interface like the redirector is

"technology." Microsoft has made the redirector source code available to selected vendors apparently in exchange for things it wanted. It is hard to have such technology exchanges when the "technology" is nothing more than a chapter in a book.

There is a detectable pattern in the things that Microsoft doesn't document as well as to the things it takes many years to document. The interface as present in DOS 2.0 is thoroughly documented into DOS 5.0 and 6.0. A specific example: Microsoft consistently underestimates the need that programmers have for low-level information about its operating systems. The unconscious Microsoft attitude seems to be that if you aren't working at Microsoft version 1.0 or 2.0 you're not going to deal with SFT chains and CDS pointers to the best place. What do they want to know that for? Of course many people outside Redmond don't share this attitude and eventually Microsoft does breakdown and documents at least some of the low-level interfaces that a lot of developers need. Microsoft may be showing some new openness in its Win32 SDK, which includes the source code for sample utilities, such as DIGDIT, PVIEWER.SPY, and WALKER. Source code. What a concept.

Another reason Microsoft does not document some important DOS functions is that it is one developer at Microsoft who put it succinctly at the company is "too busy ahead of ourselves." Work third party vendors need something that works in real-mode running DOS 6.0 today; developers at Microsoft are already thinking about and preoccupied with DOS 7.0. "[40h] is an area I discourage that's going away in DOS 7.0".

Microsoft's corporate words doesn't want to document things that it knows or thinks or hopes or prays will go away in some future version of the operating system. It is commendable that the company is so forward-looking, but this does little good to the third party vendor writing programs have perhaps painted themselves into a corner and need to accomplish some of what was *today*.

From Microsoft's perspective, how much energy and functionality it puts into supporting such things pellect sense to remove this support DOS and to tell developers that if they touch those areas and use those, their programs might or might not work in future releases. Microsoft has standard policy statement about programs that use undocumented DOS functions and data structures. Regarding the Use of Undocumented MS DOS Features *Quid Pro* September 5, 1988:

> Microsoft does not support any information about undocumented features. We feel this calls flags of developers to undocumented features. We feel that developers should not give NO guarantee that they will work in future releases of DOS. If you have found these features to be very useful, we encourage you to write to us and suggest that they be supported. There is a good chance that your application will not work in future DOS versions. We strongly advise against using undocumented features for these reasons and we will provide no information about their use.

Once a software developer documents some feature of a product, he/she is almost obligated to support that feature in future releases. Microsoft has enough problems upgrading existing MS-DOS that it has already committed. The coexistence of non-CP/M-compatible media such as Disk Control Blocks (DCBs) and the existence of the DOS Program Segment Prefix (PSP) are good examples. The DCB is a good example of why operating system internals should not be exposed to application. Documenting features can make it tough to change them later and can thus create maintenance.

So far, Microsoft's reasons for failing to document key interfaces look pretty mundane. Now, it seems particularly sinister, conspiratorial or even the product of mass conspiracy was at work.

But this passive-aggressive practice of neglecting to document certain well-known facts does have broader implications. The problem isn't "conspiracy" which seems to be a word that is invariably used to create fear and say that anything could possibly be true. Redmond is not a bastion of a conspiracy towards facts. But the problem isn't conspiracy, it's *monopoly*. Given Microsoft's 95% market share in PC operating systems, this sounds alarming, plausible. The problems with monopoly are well known. Why should Microsoft be any different?

Documentation and Monopoly

What does Microsoft's position as monopoly supplier of DOS have to do with its failure to document key parts of DOS? As noted earlier, the computer trade press may have wrongly focused on possible benefits that Microsoft applications derive from this arrangement and talked to little the benefits that DOS itself derives from undocumented interfaces.

To start, how was Microsoft managed to keep such a lucrative market as DOS almost entirely to itself? Simple economics would tell us that, given the relative simplicity of the DOS interface and given the huge profits that could be made by taking even a small piece of the DOS market away from Microsoft (see Chapter 4), Microsoft would have more competition for DOS. Why aren't there a dozen or more other companies producing high-volume DOS workalikes, in the same way that there are many competing word processors? Why is there little competition for DOS software?

One explanation is that PC operating systems might constitute a so-called "natural monopoly," that is a market in which ruthless competition drives prices up rather than down. Microsoft itself may believe that DOS is a natural monopoly. Manes and Andrews' biography quotes Bill Gates at a Rosen Research Personal Computer Forum back in May 1981, discussing how volume and standards might lead to a natural monopoly:

> We have several standards. . . . It's only through volume that you can offer reasonable software at low prices. Standards increase the basic machine you can sell into . . . . [Visicalc] established a standard in some ways. It leads to a . . . [n]ew data product category . . . a category monopoly, where somebody proposes documents properly trains, proposes a particular package and through momentum over loyalty, reputation, successive and prices builds a very strong position with that product.

Gates probably understood the connection between volume and standards earlier than anyone else in the PC software industry, which (industry of course) largely defined in the first place. Still it is somewhat amusing that Gates speaking of monopoly over back in 1981. If the PC operating system is a natural monopoly, shouldn't it come under some form of government regulation, just like telephone service, electricity and electric utilities? The idea that Microsoft might consider the PC operating system a natural monopoly is particularly worrisome given the company's clear trend of putting more and more functionality into the operating system, particularly Windows, that was previously thought of as part of applications. The Windows OLE 2.0 specification is a good example. Does this monopoly extend to the undocumented interfaces?

But even if we accept how there is an "natural" monopoly here. There are certainly many different ways to implement undocumented DOS interfaces, we'll get to the undocumented parts of the interface a little later. Note: The existence of some strong competitors in this arena would drive prices down, perhaps. While developers would quite rightly not welcome the presence of multiple DOSs or multiple implementations of Windows, it would be a testing nightmare, at least at first, overall consumers would benefit. Figure competitive market for DOS. Just as competition from AMD and Cyrix and now perhaps Motorola's PowerPC has helped Intel speed up its product development cycle, so the would competition for DOS make Microsoft more innovative.

DOS evolution has stagnated greatly because of the lack of competition. And what little advances there has been since MS-DOS 4.0 has come from changes made in DR DOS (see Chapter 4). Of course, some of the relative stagnation in DOS is based on the need for backward compatibility. But if there were better competition for DOS in the same way that there is for word processors and spreadsheets, Microsoft's "Chicago" would probably have been out by now. With little competition, Microsoft was able to starve its effort DOS and instead devote its efforts to efforts such as NT. The less competition it had for DOS, the more Microsoft was able to ignore DOS and simply milk it as a "cash cow."

The Microsoft near monopoly on DOS provides little benefit to consumers. DOS is not a natural monopoly. But then what explains the lack of competition in this lucrative market? The incentive menace to developers if there were more than one important DOS is one explanation. Microsoft's per machine rather than per copy OEM pricing of DOS is another. But an additional explanation and one which will return us to the subject of undocumented interfaces is the fear of incompatibility. A key to Microsoft's near monopoly over DOS is the notion that the only possible DOS is MS DOS. Because DOS itself is a rather small piece of code which has been hugely leveraged into an incredible business and because implementing the documented portions of the DOS interface would be relatively simple there are probably infinite ways to implement INT 21h API 440h without infringing on Microsoft's copyright. Microsoft's DOS monopoly depends largely on this issue of "compatibility."

But compatible with what? It is relatively simple to be compatible with the documented DOS interface. Failure to do so spells trouble. So what does this "compatibility" mean?

In part of course compatibility is just marketing propaganda information number two Microsoft wants to promote the idea that MS DOS is the most conceivable DOS. In this sense "compatibility" is just another word for saying "anything else is not MS DOS."

But an operating system rarely works as part of an integrated package together with other products. So there is something genuine to the issue of compatibility. It usually means compatibility with *undocumented* interfaces. Microsoft Excel is not compatible with documented interfaces just as long Microsoft can make a good argument that only MS DOS implements all the undocumented DOS interfaces correctly and that therefore only MS DOS is "100% DOS compatible." This appears to be the core of Microsoft's defense of the VARD code in Windows 3.1 that only DR DOS will fail "100% DOS compatibility" whereas it would pass the VARD test. As we saw earlier the VARD test for 100% DOS compatibility depends entirely on undocumented interfaces. Producing a compatible DOS then is largely a matter of getting the undocumented interfaces right.

Because it is relatively easy for competitors to be compatible with a documented interface companies try to create what Ray Noorda calls "embrace and lengthen" by selectively documenting only parts of their product's interfaces. Consequently in mid Microsoft has added code to shore up its dominance of the DOS market. Whenever an application tool was the advice of a best selling book on undocumented DOS services and uses the structures returned by DOS in many successful applications now fail if they are not run by MS DOS. They fail not due to bugs in the applications but rather than due to the DOS standard control. Conversely relying on undocumented calls and structures makes development for a clone of DOS worthless.

But for Microsoft to defend its monopoly it might seem that undocumented interfaces important applications have to be secret. How could it be true that Microsoft would in some way actually have to encourage key vendors to use calls and structures that it does not document? Microsoft indeed does claim to help ISVs use undocumented calls when necessary. This has also raised the question of why Microsoft doesn't just document the calls. The possibility of using undocumented interfaces essentially as a form of product differentiation provides one answer to that question.

Indeed many so called "undocumented" interfaces are actually "selectively documented" interfaces in which Microsoft has selectively allowed some of its competitors and or customers access to an interface while denying similar access to other companies and to the rest of the developer community. There are numerous instances of this including the network redirector the Global EMM Import specification and the HIMEM code for Windows 3.1.

Earlier I was noted that Orson Wells" never said anything more than what software engineering texts sometimes call "abstraction" or barriers that is narrow well documented interfaces. But the software engineering texts fail to mention that to properly document interfaces also to allow them open to potential competition. Conversely undocumented interfaces are a way of creating and reinforcing a *monopoly standard*.

Owning a special standard depends on publishing this standard and having others write to it. Otherwise the standard is worthless. But to publish a standard opens it up to potential competition from clone-makers, reverse-engineers and so on. Is there any trick that would allow one to own a certain standard, prevent cloning or at least delay competition? MS-DOS shows that the answer is yes, and undocumented DOS interfaces on which key applications rely is part of how the trick works.

Fear of Undocumented DOS

We've discussed that MS-DOS includes a lot of undocumented functionality. Microsoft doesn't document these features because it wants the freedom to change or discard them in future versions of MS-DOS, and in most cases the cases we've discussed these features may be more useful to Microsoft in their role as internal developer. Armed with *Undocumented DOS* you now know all about these functions and what's not to like. It is interesting to know that MS-DOS puts the address of its internal variable table in register ES:BX after function 52h. But can you use this and still run programs?

Programming outside what is allowed by Microsoft generally sets off alarm bells. So do other programmers as well. We've mentioned areas of compatibility, the use of reserved, undocumented or unspecified features which can cause problems for portable software. Use of undocumented features is not generally advised in shrink-wrapped software which is to be sold to the public. It's said to believe that using undocumented calls is a quick and easy way to write stable and correct software for MS-DOS.

There is a certain amount of suspicion surrounding undocumented DOS and some programmers have found it easier to take the dogmatic view that programmers should never ever use undocumented DOS functions. Typical of this point of view is Ray Duncan's book *Advanced MS-DOS Programming*. Duncan, a well-known author and consultant on DOS programming, writes in his introduction to INT 21h programming. Thomas A. Wadlow, *Writing Robust Software for MS-DOS*, 1988" writes

> None of the programs in this book use the INDOS call and for good reason. INDOS is "undocumented" — common but has two warnings. The first is of course that you cannot look up the INDOS command. The second is that Microsoft, the vendors of DOS, reserves the right to change or delete any function from subsequent versions of DOS. In fact the INDOS call was known by a number of names under DOS version 2.x, which is a result of the internal reorganization. In DOS version 3.x the call still exists but has changed quite a bit from its earlier version. In DOS 4.00 this function does something quite different; thus calls to the INDOS function will fail miserably.
>
> For that reason, use of the INDOS function call or any undocumented DOS function is not recommended.

The DOS reference in the back of Wadlow's book has entire pages with only a note at the top such as:

```
AH = 034H (52)          Unsupported
INT 021H (33)           Universal Function
```

The rest of the page is left blank!

You've seen that the internal variable INT 21h function 34h. If you have all the information about the program that it has to run DOS version to the next, then calls to the INDOS function will *not* "cause disaster". Ray Duncan's INRs from the first edition of *Undocumented DOS* used this then undocumented function and these programs work correctly in DOS 2.x, 3.x, 4.x, 5.x and 6.x in the DOS box in OS/2 2.x and in Dos Navigator for DR DOS.

In fact what happened with function 34h was that, far from failing miserably, Microsoft documented it. In the most recent undocumented calls are destined to become documented, then using such functions can be nothing more dangerous than give you a year or two jump on your more cautious competitors. Another good example of this is the Set/GetSelectorArmed Base functions in Windows 3.0 which were suspected that Microsoft documented them in Windows 3.1. Was it a mistake to use these when they were undocumented? In retrospect clearly it wasn't. There is something of a

Heisenberg effect at work here. The reason that previously undocumented functions have to be documented is that programmers start using them. Documentation is to an extent market driven.

An informal poll seems to indicate that developers of commercial PC software—software that must maintain a high degree of consistency and compatibility sometimes on millions of different machines—are in general less fearful of undocumented DOS than programmers whose work needs to run on only one or two machines. Various parties

One explanation is simple. Later is month's mass marketed shrink wrapped utilities rather than say in house databases or vertical market applications that require undocumented DOS. Another explanation is that programmers who work for large commercial software houses can better afford the possible higher cost of working with undocumented DOS. Software that uses these functions perhaps requires more testing and more maintenance than that which uses normal DOS code.

In any event attitudes toward undocumented DOS resemble current opinions about the "goto" construct in programming languages. Many professional programmers recognize that goto possibly disguised as "long jump" is sometimes necessary. But goto programmers should avoid undocumented DOS but not when it's the only available. Software construction involves tradeoffs and compromises, not fixed dogma. Software construction appears to be engineering not religion.

Even though use of undocumented API calls is particularly prevalent in widely distributed software packages for the IBM clone, there persists the view that using these functions is somehow immoral, or only the home hobbyist can do it. For example, *Peter Norton Windows 3.0 Power Programming Techniques* by Paul Yao and Peter Norton, says

> It has been our experience that "undocumented goodies" are interesting to look at but dangerous to include in software that is intended for general distribution.

While this is an excellent book, this particular statement is quite odd. Windows itself as well as such riches heavily on undocumented DOS calls, and Windows was certainly intended for general distribution. Moreover, the point of Peter Norton's own products, the Norton Utilities and the Norton Desktop for Windows, is to reach out both undocumented DOS and Windows calls. Well maybe Peter didn't read what Paul wrote.

Ain't Misbehavin'

As we've seen, most of Windows software and virtually all programs for the PC use undocumented DOS. With some exceptions like the Windows DOSMGR.VxD, these programs tend to make use of one or two undocumented DOS calls. This is not what has been termed "well behaved" software. However, it takes only one undocumented DOS call to change the nature of a program.

Let's say that you've written a program that uses only documented DOS calls. Is your program "well behaved"? Let's hope so. Chapter 10, "Compatibility and Portability," in Duncan's *Advanced MS-DOS Programming* categorizes MS-DOS applications by degrees of compatibility. Duncan uniquely classifies programs that use undocumented DOS to the innermost circle of this DOS inferno.

> Device driver applications are those that rely on undocumented MS-DOS function calls or data structures, except for the documented MS-DOS or ROM-BIOS interrupts, or direct access to mass storage devices, bypassing the MS-DOS file system. These programs tend to be extremely sensitive to their environment and typically must be "adjusted" in order to work with each new MS-DOS version or PC model. Virtually all popular terminate and stay resident (TSR) utilities, network programs, and disk repair/optimization packages are in this category.

The most important sentence here is the last one. If you write "well behaved" DOS applications, you are in good company. Indeed, the purpose of *Undocumented DOS* is to show how you too can write ill behaved programs such as Microsoft Windows, the Norton Utilities Speeder, and QEMM. All these programs do tend to be extremely sensitive to their environment. Some of them do have to be updated from time to time to work with each new MS DOS version. Start using undocumented DOS, and that will be true of your software as well.

Unexpected results are a fact of life in the MS DOS world. In fact, using undocumented DOS can make you change your habits and habitudes as the standard practice of bypassing DOS and writing directly to the hardware. Windows was supposed to eliminate that problem, but as *Undocumented Windows* showed, it only led that problem for another one, more undocumented interfaces.

Undocumented functions and data structures for many important tasks is why you must learn about MS DOS. It rarely does about any sort of standard recommended programming practice before we start knocking MS DOS, though let's not forget that it for no other reason than that it has fallen on the crutch of the PC's great success. DOS has succeeded in a way that no other, supposedly better operating system can match. DOS, warts and all, is an inescapable reality. Using undocumented DOS can not be a place in any software engineering curriculum, but it is a good exercise in confronting your principles with the real world.

The practical question is, what we can salvage of good engineering practice as we make our dash into undocumented DOS. This book presents many techniques for using undocumented DOS in a reasonably safe and reliable manner. Some of the techniques recommended in this book are:

- Rigorous checking of the MS DOS version number (not necessarily DOS 5.0 and higher; see Chapter 2).
- Verifying the basic integrity of undocumented DOS externals by performing an undocumented DOS call and comparing its output with a known value.
- Computing structure sizes dynamically as a double check for sizes computed from the DOS version number.
- Never use an undocumented function or structure when there's a documented alternative. Do not waste effort in looking for the documented alternative; don't just assume there isn't one.

Despite the risks, undocumented DOS are obligated to do a *better* job of DOS version checking, error checking, and housekeeping than the many other programs that otherwise play by the book. (Our favorite technical term for this is "the stupidest thing I've ever heard." All programs, whether they use undocumented features or not, have to do rigorous error checking.") Most of the programs in *Undocumented DOS* and its accompanying disk all work properly in MS DOS versions 2.x, 3.x, 4.0, and 5.0. Some of the programs have been ported to protected mode using DOS extenders. Many have been tested under all Borland or Microsoft C++ compilers, using Windows, SHARE, DesqView, QEMM, and 386Max with various DOS components loaded into upper memory.

Many of the programs in this book have also been tested under environments such as the DOS compatibility boxes found in OS/2 1.x and 2.0 and Novell's DOS 7 DOS. See Chapters 3 and 4. These environments rate a low priority in our testing, but it is important to gauge the quality of their support for undocumented DOS because any support they do provide is *completely intentional*. Unlike versions of MS DOS itself, which may support one or another undocumented DOS feature simply out of inertia, DOS environments can only support an undocumented DOS function call or data structure if someone consciously puts it there.

So, here is a large collection of popular PC software that uses undocumented DOS. Are the vendors of these programs going to get deformed with the next version of DOS? It's instructive to read what Mark Russinovich, Chief Architect for System Software, said about this issue. Gordon Letwin, *Inside OS/2*, 1988:

It may seem that if a popular application "pokes" the operating system and otherwise engages in unsavory practices that the authors or users of the application will suffer because a future release such as OS/2 may not run the application correctly. To the contrary, the market dynamics state that the application has now set a standard, and it's the operating system developers who suffer because they must support that standard. Usually, that "standard" operating system interface is not even known, a great deal of experimentation is necessary to discover exactly which undocumented side effects, system internals, and timing relationships the application is dependent on.

In other words, when popular applications use undocumented DOS, ultimately it is Microsoft which suffers the inconvenience, not the application's developer. As noted earlier, Microsoft may also derive some benefit in that the popular application has locked itself into MS-DOS. The real suffering may be done by vendors of would-be DOS workalikes. In any case, smaller developers meanwhile, can ride the coattails of the larger developers. For better or for worse, if enough important applications use undocumented DOS, yesterday's undocumented hack becomes tomorrow's standard. The market has spoken. Amen.

CHAPTER 2

Programming for Documented and Undocumented DOS: A Comparison

by Andrew Schulman

Let's pretend we work in the installation software group of a commercial software company. For some reason, we have been asked to produce a small utility that, when run from a DOS batch file, returns the number of logical drives on the system [illegible] corresponds to the LASTDRIVE statement in a user's CONFIG.SYS. Perhaps the company is installing software on a Novell NetWare 3.x network, where LASTDRIVE determines the starting letter for network drives.

The utility is to be called LASTDRV.EXE, and the idea is that when the utility exits back to DOS, it should return [illegible] corresponding to LASTDRIVE. For example, if LASTDRIVE=E, then LASTDRV.EXE should return [illegible] DOS errorlevel that [illegible] can be interrogated using the IF ERRORLEVEL [illegible] MS-DOS documented batch language.

The LASTDRV utility should also [illegible] LASTDRIVE [illegible] in such a way that redirecting the program['s output] to NUL [illegible] output. For example, [illegible] LASTDRIVE [illegible] someone in the [illegible] some large software companies work that way [illegible] something like the following batch file:

```
echo off
rem need6.bat
lastdrv > nul
if errorlevel 6 goto end
echo Requires at least six drives
:end
```

Now, how do we write LASTDRV.EXE? [illegible] CONFIG.SYS file and then locate the LASTDRIVE [illegible] from the fact that LASTDRIVE didn't make its appearance until DOS 3 [illegible] the default LASTDRIVE [illegible] CONFIG.SYS [illegible] the one with which the system was booted. It also appears to be impossible to locate the boot drive reliably in MS-DOS prior to version 4.0 [illegible] versions of DOS, INT 21h function 3305h returns this value.)

If we are writing in a high-level programming language like C or Pascal, it is unlikely that the compiler's run-time library comes with a function that returns the number of drives. [illegible] Microsoft C [illegible] and C [illegible] both of [illegible] floppy drives [illegible] what about [illegible] disks?

[illegible] of DOS *logical* drives [illegible] the PC's ROM BIOS [illegible] the functional specification [illegible] for this [illegible] logical drives [illegible] include RAM disks, network drives, CD-ROM drives, tape back

up drives and the like. Logical, in other words, means both physical drives and *phantom* drives. As shown in Chapter 8 of the DOS Inside system, much of DOS's extensibility comes from the ability to have drive letters assigned to things that aren't really drives at all. In other words, a logical drive is an MS-DOS construct having little to do with PC hardware or the ROM BIOS. How are we going to write the LASTDRV program?

Using the example of LASTDRIVE, this chapter looks at how to incorporate the information in the rest of its book into working code in C, 80x86 assembly language, Turbo Pascal, and BASIC. It also discusses an important issue: when and how to use undocumented features, while showing that certain PC programming tasks absolutely require them.

In the course of this chapter, it will also become clear that exploiting undocumented features of MS-DOS usually requires only a few dozen lines of code. On the other hand, programs that use undocumented DOS services must be more aware of the MS-DOS version number than code that uses only documented DOS. In particular, while undocumented MS-DOS *function calls* have remained remarkably stable from version to version of DOS, to another, the equally important DOS internal data structures vary widely with each new release of the operating system. Programs that use undocumented DOS must be prepared to deal with this problem. In DOS 5.0 and higher, this issue is further complicated by the fact that the supposed DOS version number can be modified on a per-application basis. Gross.

This chapter assumes that you want to access undocumented DOS from a DOS program. While this assumption is valid for most professional developers, more and more developers are writing for protected mode environments such as Microsoft Windows. Often, these new programs must still talk to DOS, and sometimes they must even access undocumented DOS functions and access undocumented DOS data structures. Part 3 of Chapter 1 discusses the problem of accessing undocumented DOS from protected mode Windows.

Using Documented DOS Functions

Before examining how to use undocumented DOS in programs, let's review how to use documented DOS function calls. This detour into documented DOS—we might even say over-documented DOS because so much has been written about it—will pay off when we work with programs using undocumented DOS. If you know how to call or debug DOS from your chosen programming language, skip to the section on using undocumented DOS. Don't skip the entire chapter though, even if you read only the first section. A lot has been added since DOS 1.0, including a program that examines some DOS internal data structures. A peek at the disassembled source code for DOS 4.0's extension to locking DOS, and discussion of lots of new strategies covering the DOS version number.

Before we jump into the code for LASTDRIVE, the first thing to do is browse through a reference book on DOS programming, looking for an INT 21h function that returns the number of logical drives.

Upon doing so, Microsoft's official *MS-DOS Programmer's Reference*, we find that INT 21h function 0Eh, which selects the current disk drive in the system, also works somewhat illogically since the two-letter function name suggests that it returns the total number of drives.

```
Int 21H function 0EH
Select Disk
Selects the drive specified in DL (if valid) as the default drive
Call with
    AH   0EH
    DL   drive code (0=A, 1=B, etc.)
Returns
    AL = number of logical drives in system
```

In a single-drive IBM PC with DOS 1.x and 2.x present at more customer sites than you would like to think, DOS returns AL = 2 because DOS supports two logical drives, A and B. These drives hang off the system's single physical floppy drive. In DOS 3.x and higher, AL returns a the drive code corre

sponding to the LASTDRIVE entry in CONFIG.SYS, for example, six if LASTDRIVE=F: is in effect if there is no LASTDRIVE entry, or else the actual number of block devices on the system if there are more than five.

This return value is exactly what we want. Actually, it's *almost* what we want. It's also a portable special case. DOS machines using Novell NetWare, the same function 0Eh returns in AL a number equal to LASTDRIVE. Over the universe of PC systems running Novell NetWare, this is an important exception to which we will return later in this chapter.

But how do we get the current drive we want from this Select Disk function without also selecting a new current drive? The answer is obvious: Especially the drive that is *already* current is the "new" one. Where do we find the current drive? Once again we dig through our DOS programmer's reference. DOS programming has a lot in common with using a mail order or gardening catalog, and I've stumbled upon function 19h (Get Current Disk).

```
Int 21H Function 19H
Get Current Disk
Returns the drive code of the current, or default, disk drive
Call with:
    AH = 19H
Returns
    AL = drive code (0=A, 1=B, etc.)
```

It's simple to take all this information and turn it into a program. In the remainder of this section we will produce versions of LASTDRV.EXE in assembly language, C, Turbo Pascal and QuickBASIC. This is not what we will call "strategic *document it* programming" of the DOS programmer's interface, in preparation for our descent into the world of multitasking DOS.

DOS Calls from Assembly Language

The small assembly language program in Listing 2-1 shows how the reference material on DOS functions 0E and 19H translates into a working version of LASTDRV.EXE. This code also uses DOS function 09h to display a part which can be redirected to a file or to a NUL bit bucket. Finally, the program calls DOS function 4Ch to exit to DOS, passing the numeric value of LASTDRIVE as the return code.

Listing 2-1: LASTDRV.ASM

```
; LASTDRV.ASM -- uses only documented DOS
; masm lastdrv,
; link lastdrv,
_STACK  segment para stack 'STACK'
_STACK  ends
_DATA   segment word public 'DATA'
msg     db      'LASTDRIVE='
dletter db      ?
        db      0dh, 0ah, '$'
_DATA   ends
_TEXT   segment word public 'CODE'
        assume cs:_TEXT, ds:_DATA, ss:_STACK
main    proc    near
        mov     ax, _DATA
        mov     ds, ax          ; set DS to data segment
        mov     ah, 19h         ; Get Current Disk function
        int     21h             ; call MS-DOS
        mov     dl, al          ; AL now holds current drive
        mov     ah, 0Eh         ; Select Disk function
        int     21h             ; call MS-DOS
        mov     bl, al          ; LASTDRIVE in AL; save in BL
```

```
        add     al, ('A' - 1)   ; convert to drive letter
        mov     dletter, al     ; insert into string

        mov     dx, offset msg  ; string in DS:DX
        mov     ah, 9           ; Display String function
        int     21h             ; call MS-DOS

        mov     ah, 4Ch         ; Return to DOS
        mov     al, bl          ; LASTDRIVE is exit code
        int     21h             ; call MS-DOS
main    endp

_TEXT   ends

        end main
```

You can assemble LASTDRV with any number of assemblers and then link it with any MS-DOS compatible linker using the Microsoft Macro Assembler (MASM)

```
masm lastdrv.asm;
link lastdrv.obj;
```

Or, using Borland Turbo Assembler (TASM)

```
tasm lastdrv
tlink lastdrv
```

When run, the program produces the desired output, for example

```
C:\UNDOC2\CHAP 2 > lastdrv
LASTDRIVE=M
```

DOS Calls from C

There is a problem making DOS calls using the C programming language. It's not that it is difficult to access MS-DOS services from C—the problem is there are too many different ways to do so. Not satisfied with one technique where a dozen techniques would do, C compiler manufacturers for the PC, such as Microsoft, Borland, Watcom, and MetaWare, one wonders now and then, the longer the PC marketplace can support so many different good C compilers, offer a wide variety of techniques for calling MS-DOS and ROM-BIOS services. Having so many different ways to perform the same operation is confusing.

The problem isn't limited to the compilers, however. Ultimately, we have to ask why MS-DOS itself doesn't come with a set of C-callable functions like Windows does. The only thing approaching a standard programming interface for MS-DOS is the set of functions such as `dos_setdrive()`, `dos_allocmem()`, and `dos_findfirst()` that appear in the Microsoft C/C++ DOS.H header file. Other C compiler vendors such as Borland and Watcom have adapted these as well.

On the other hand, the lack of a standard programming interface in MS-DOS has done not much to stop MS-DOS's spectacular success. It may even have aided the success slightly, because it gives programmers one more thing to muck around with. In any case, we need to discuss a few of the techniques that you can use to make MS-DOS calls from C, including the `int86()` and `intdos()` functions, inline assembly language, and register pseudo variables.

int86() For a long time, the most popular way of calling system services from C on the PC was to use the `int86()` function, which is an Intel 80x86 software interrupt. C compilers for the PC such as Microsoft C/C++ and Borland C++ come with a DOS.H include file with prototypes for `int86()`, `int86x()`, `intdos()`, and so on. These functions work with two structures, known REGS and struct SREGS, which contain an image of the actual CPU registers. To see how functions such as `int86x()` are implemented, see the source code for your compiler's run-time library—for example, BORLANDC\RTL\CLIB\INT86.C or .ASM.

Listing 2-2 shows LASTDRV.C, which uses int86. This can be compiled with any Microsoft-compatible C compiler for the IBM PC, using either the full screen or the command-line version of the compiler.

Listing 2-2: LASTDRV.C

```
/*
LASTDRV.C -- Uses only documented DOS, illustrates int86()

Microsoft C/C++:  cl lastdrv.c
Borland C++:      bcc lastdrv
*/

#include <stdio.h>
#include <dos.h>

main(void)
{
    union REGS r;
    unsigned lastdrv;
    r.h.ah  = 0x19;                 /* Get Current Disk */
    int86(0x21, &r, &r);            /* call MS-DOS */
    r.h.dl = r.h.al;                /* r.h.al now holds current drive */
    r.h.ah = 0x0E;                  /* Select Disk */
    int86(0x21, &r, &r);            /* call MS-DOS */
    lastdrv = r.h.al;               /* r.h.al now holds number of drives */
    fputs("LASTDRIVE=", stdout);    /* output string */
    putchar('A' - 1 + lastdrv);     /* output drive letter */
    putchar('\n');                  /* output newline */
    return lastdrv;                 /* return drive number to MS-DOS */
}
```

The C source code in LASTDRV.C is almost half the length of the corresponding assembly language code in LASTDRV.ASM. Development and the size of the executable program from less than 600 bytes in assembly language to almost 5,000 bytes in C. Why does LASTDRV.C compute the LASTDRIVE= entry using a letter A–Z rather than a number 1–26? Because while function 0Eh in both DOS and BIOS uses zero-based drive letters (0=A, 1=B, etc.), function 19h returns the number of drives, not the number of the last drive, because DOS drive letters are zero-based. LASTDRV.C must subtract 1 from the number of drives to produce the number of the last drive, which can then be added to 'A' to produce the last drive letter. LASTDRIVE=

Inline Assembler A better way to write PC system-level software in C is to use a built-in assembler that is part of the compiler. Inline assembly code directly inserts machine-specific instructions into your C code. Inline assembly code is inherently nonportable, because it is specific to the 80x86 CPU. You can't expect MS-DOS or ROM-BIOS calls to work on non-Intel architectures, so software is rarely portable to new systems anyway. Inline assembly language is a powerful tool for writing system-level software.

Microsoft C/C++ and Borland C++ both include an inline assembler. There are a few differences between the Microsoft and Borland elements. A key difference is that Borland does not allow labels in an _asm block. Both Borland and Microsoft provide a stand-alone assembler, right with their C compiler, but Borland's assembler is not compatible with the rest. Borland's compiler passes the entire assembler through to a separate assembler such as TASM or MASM, allowing you to include assembly language directives such as DB, as well as high-level macros or 386 instructions directly in your C code. This assembler is more difficult to use than Microsoft's inline assembler.

In LASTDRV2.C (Listing 2-3), note how the preprocessor directives ensure that the compiler can support an inline assembler. Most C compilers identify themselves with a preprocessor definition. Borland C++ provides both __BORLANDC__ and __TURBOC__ for backward compatibility with the older Turbo C and Turbo C++ compilers. __TURBOC__ Microsoft C/C++ provides _MSC_VER, which contains the compiler version number, such as 700 decimal for 7.0.

Listing 2-3: LASTDRV2.C

```
/* LASTDRV2.C -- uses only documented DOS, illustrates inline assembler */

#include <stdlib.h>
#include <stdio.h>

main()
{
    unsigned lastdrv;

#ifdef __TURBOC__
    asm mov ah, 19h         /* C-style comments only */
    asm int 21h
    asm mov dl, al
    asm mov ah, 0x0e        /* C-style hex */
    asm int 21h             /* assembly-style hex */
    asm xor ah, ah
    asm mov lastdrv, ax     /* refer to C variables */
#elif (defined(_MSC_VER) && (_MSC_VER >= 600)) || defined(_QC)
    _asm {
        mov ah, 19h         ; can include assembly-style comments
        int 21h             /* and C style as well */
        mov dl, al          // and this style as well
        mov ah, 0x0E        ; can include C-style hex numbers
        int 21h             ; or assembly-style hex numbers
        xor ah, ah
        mov lastdrv, ax     ; can refer to C variables in _asm
        // Borland would not allow a goto/jmp label here!
        }
#else
#error Requires inline assembler
#endif

    fputs("LASTDRIVE=", stdout);
    putchar('A' - 1 + lastdrv);
    putchar('\n');
    return lastdrv;
}
```

These statements mask the assembly back show the odd mixtures of C and assembly language that you can produce. You do have to be careful when using inline assembly language. In particular, you must know your compiler's rules about preserving registers. For Microsoft and Borland, the rules are simple:

- You are free to change AX, BX, CX, DX, and ES.
- Inside a function, you can change BP.
- You must always put back any changes to the DI, SI, DS, SS, and SP registers, however.
- Because the compiler has no idea what you're doing with the registers using the inline assembler, it turns off global optimizations. In this case, Microsoft C/C++ issues an "inline assembler precludes global optimizations" message.

Register Pseudo Variables

Borland provides yet another way to write low-level code: register pseudo-variables. Not to be confused with C register variables, register pseudo-variables map onto the CPU registers but look like C variables. For example, assigning to AX is the same as doing a MOV to the AX register. Listing 2-4 shows LASTDRV3.C, which uses register pseudo-variables to implement yet another LASTDRV utility.

Listing 2-4. LASTDRV3.C

```
/* LASTDRV3.C — uses only documented DOS,
illustrates register pseudo-variables */

#ifndef __TURBOC__
#error This program requires Borland C++ or Turbo C
```

```
#endif
#include <stdlib.h>
#include <stdio.h>
#include <dos.h>

main()
{
    unsigned lastdrv,
    _AH = 0x19,
    geninterrupt(0x21),
    _DL = _AL;
    _AH = 0x0E;
    geninterrupt(0x21);
    lastdrv = _AL;
    fputs("LASTDRIVE=", stdout),
    putchar('A' - 1 + lastdrv),
    putchar('\n');
    return lastdrv;
}
```

Note that geninterrupt 0x21 is *not* a function call but a compiler directive to emit an INT 21h directly into the compiled code. And although the register pseudo-variables such as _AL are extremely handy, the code generated by the compiler of course uses the same CPU registers as your code, so you can't rely on values staying in the registers for very long.

DOS Library Functions

Actually, neither int86() nor _asm blocks are necessary here. As mentioned earlier, most C compilers for the PC provide a set of functions that map directly onto the most popular DOS functions. Microsoft C provides functions with names such as dos_getdrive() and dos_setdrive(), for example. Borland C++ supports these as well as older Borland-specific functions such as getdisk() and setdisk(). The DOS setdrive() function is the same with the important exception of Novell NetWare, which would require equivalent to setdisk(getdisk()).

```
printf("LASTDRIVE=%c\n", 'A' - 1 + setdisk(getdisk()));
```

If functions such as setdisk() and getdisk() or dos_setdrive() and dos_getdrive() didn't exist, it would be easy to create them. This is a matter for either assembly language:

```
void _dos_setdrive(unsigned drive, unsigned *p_lastdrive)
{
    _asm mov ah, 0Eh
    _asm mov dl, byte ptr drive
    _asm int 21h
    _asm mov bx, p_lastdrive
    _asm xor ah, ah             /* fake 21/0E return value in AL, 0-extend */
    _asm mov word ptr [bx], ax  /* into AX, move into caller's pointer */
}

void _dos_getdrive(unsigned *p_currdriv)
{
    _asm mov ah, 19h
    _asm int 21h
    _asm mov bx, p_currdriv
    _asm xor ah, ah
    _asm mov word ptr [bx], ax  /* assuming near pointer! */
}
```

DOS Calls from Turbo Pascal

What about calling MS-DOS functions from other high-level languages? In some ways it is much simpler to make these calls from other languages such as Turbo Pascal because you don't have to worry about which method to use. As noted earlier, having the wide variety of techniques available

Turbo C++ Borland's latest C++ compiler, because programmers and writers end up spending too much time deciding which technique to use.

Calling DOS functions from Turbo Pascal requires the DOS unit, which includes the Registers variant record similar to Turbo C's REGS in C and the MsDos() function. LASTDRV.PAS in Listing 2-5 shows this:

Listing 2-5: LASTDRV.PAS

```
{ LASTDRV.PAS -- uses only documented DOS }

program LastDrv;
uses Dos;
var
    r   Registers,
    lastdrive   byte,

begin
    with r do begin
        ah  = $19,          { Get Current Disk }
        MsDos(r),
        dl  = al,
        ah    $0E,          { Select Disk }
        MsDos(r),
        lastdrive := al;
    end,

    Writeln('LASTDRIVE=', Chr(Ord('A') + 1 + lastdrive));
    Halt(lastdrive),
end
```

Note that Pascal's *with* construct allows us, for example, to refer to fields of the Registers record as *ah* rather than *r.ah*.

Do you recall that version of Turbo Pascal can turn LASTDRV.PAS can into LASTDRV.EXE?

```
tpc lastdrv.pas
```

Due to Turbo Pascal's reputation for producing extremely tight code, the resulting Turbo Pascal executable file is only 2K. The smallest C version is about 4K.

There is a separate set of issues involved with making DOS calls from Turbo Pascal for Windows (TPW). For example, instead of using the DOS unit, you must use the WinDos unit. See Chapter 3 of my book for a detailed discussion of calling DOS from Windows programs. For TPW specifically, Neal Rubin's excellent book *PC Magazine Turbo Pascal for Windows Techniques and Utilities* discusses this subject at length.

DOS Calls from BASIC

How's about BASIC? LASTDRV.BAS, the version of LASTDRV in Listing 2-6, displays the LASTDRIVE= line and returns the numeric value of LASTDRIVE to the DOS ERRORLEVEL:

Listing 2-6: LASTDRV.BAS

```
REM LASTDRV.BAS -- uses only documented DOS
REM $INCLUDE: 'QB.BI'

SUB DOSEXIT(errorlevel)
    CLOSE
    DIM Regs AS RegType
    Regs.ax = &H4C00 + errorlevel   ' Terminate Process
    CALL INTERRUPT(&H21, Regs, Regs
    PRINT "this is never executed"
END SUB

DIM Regs AS RegType
Regs.ax = &H1900                    ' Get Current Disk
```

```
CALL INTERRUPT(&H21, Regs, Regs)
Regs.dx = Regs.ax
Regs.ax = &HOE00                        ' Select Disk
CALL INTERRUPT(&H21, Regs, Regs)
lastdrv = Regs.ax AND &HFF

PRINT "LASTDRIVE="; CHR$(ASC("A") - 1 + lastdrv)
CALL DOSEXIT(lastdrv)
END
```

To turn this source code into an executable file you can use either Microsoft QuickBASIC or the Microsoft BASIC 6.0 compiler. Using the BASIC 6.0 compiler the command is

```
bc /o lastdrv.bas,
link lastdrv,,,qb.lib,
```

If you are using QuickBASIC to produce a stand-alone executable file the proper incantation is

```
qb lastdrv.bas /L qb.qlb
```

Using the BC /O switch or producing a stand-alone executable file from within QuickBASIC is mandatory. Surprisingly as it seems Microsoft BASIC was not designed for returning exit codes to DOS. In order to return the value of LASTDRIVE to the DOS ERRORLEVEL variable LASTDRV.BAS uses the subroutine DOSEXIT which directly calls MS-DOS function 4Ch (Terminate Process with Return Code) and never returns. Attempts bypassing BASIC's normal exit routines has does not work from an executable file that uses the BASIC run-time modules. For example pRI NotBUsr Directly calling INT 21h function 4Ch from an executable that uses the BASIC run-time module can easily hang the machine.

There's another problem because this subroutine never returns after calling INT 21h function 4Ch, it does not give control back to BASIC's run-time module and BASIC never gets a chance to clean up after itself. The result is that you're left at the DOS prompt. This rather curious code shows how to make low-level system calls from Microsoft BASIC. It's also a useful piece of software. BASIC has many features going for it as a programming language but it's poor access to the operating system's approach is not one of them.

MS-DOS 5.0 and later comes with QuickBASIC. While an excellent addition to DOS in many ways, QBASIC's support for the CALL INTERRUPT feature, like LASTDRV.BAS uses. The CALL ABSOLUTE, PEEK and OUT statements scattered throughout the MONEY.BAS sample program source code were included with MS-DOS 5.0 to support the LASTDRV command. It seems worth the effort. And while, however, QBASIC included with DOS doesn't make it possible to do many tasks that Microsoft BASIC can't perform, the QBASIC /RUN command saves you much screen flashing to be generally useful for creating batch files and tools for DOS.

Using Undocumented DOS

Quarterdeck's expanded memory manager QEMM comes with a program called LASTDRIV.COM. All of its instances is to report the value of LASTDRIVE. Interestingly enough, this program does not use documented function 0Eh. Instead it uses undocumented function 52h. We won't see why until later. For now, though, the point is simply that Quarterdeck can do it so can you.

What better place to start using undocumented DOS than with a program like LASTDRV whose operation we already know well. In the next section we again show how to write the LASTDRV utility in assembly language, C, Pascal and QuickBASIC, but this time using undocumented DOS. In particular we highlight the larger role that the DOS version number plays when using undocumented DOS.

We started through the process of using a standard DOS programmer's reference as if it were an Oracle's apocalypse or a handbook of mathematical functions trying to find a tool that would help us write a LASTDRIVE=Z: We never found a single function called Get Last Drive, but we did find functions Get Drive Parameters and Select Disk that together achieve the same effect.

Examining the code for these functions is instructive. It's similar to setdisk getdisk. But there's something illogical about it. We've told DOS return the total number of drives when you set the current drive? MS-DOS presumably keeps the value of LASTDRIVE somewhere internally. Is there some way to find it?

Disassembling DOS

Let's use SYMDEB to disassemble the code for MS-DOS and see how it implements INT 21h function 0Eh. We can expect to see a procedure that returns a value in the AL register. Chapter 6 discusses DOS data structures. DOS internally stores the LASTDRIVE value, but it doesn't make sense to look at it here. Instead, let's look briefly at what actually happens when we call INT 21h function 0Eh.

Listing 2-7 shows the first place to look: the first few words in the INT 21h vector. Because DOS is loaded high, you'll have to take it on faith that the segment value 4C68 is correct. Below is the DOS handler for INT 21h function 0Eh. Although SYMDEB doesn't recognize running under DOS 6.0 with DOS=HIGH, it produced this disassembly. DEBUG would not work on DOS itself. It's unable to load and produces garbled results when SYMDEB is.

Listing 2-7: SYMDEB Disassembly of INT 21h Function 0Eh in DOS 6.0

```
-u fdc9 4c68
FDC9:4C68 8AC2          MOV     AL,DL
FDC9:4C6A FEC0          INC     AL
FDC9:4C6C E81B5E        CALL    4A87
FDC9:4C6F 7204          JB      4C75
FDC9:4C71 56A23603      MOV     SS:[0336],AL
FDC9:4C75 56A04700      MOV     AL,SS:[0047]
FDC9:4C79 CB            RET
```

This code is a little difficult to follow, so Listing 2-8 contains another version, suitably commented and decorated.

Listing 2-8: Commented Disassembly of INT 21h Function 0Eh

```
        select_disk_0E proc near
FDC9:4C68    MOV     AL,DL                   ; DL = zero-based drive code
FDC9:4C6A    INC     AL                      ; make one-based
FDC9:4C6C    CALL    1_select_disk           ; call internal function
FDC9:4C6F    JB      fail                    ; jump if carry
FDC9:4C71    MOV     DOS_DS:[CORRDRIVE],AL   ; 011E:0336
        fail:
FDC9:4C75    MOV     AL,DOS_DS:[LASTDRIVE]   ; 011E:0047
FDC9:4C79    RET
        select_disk_0E endp
```

The function labeled select disk is not shown here, but it sets, among other things, it calls the DOS internal set drive function. It's the same piece of code that is invoked if you issue the undocumented INT 21h AX = 440Dh Set Drive Code call described in Appendix. DOS can call this function directly without going through INT 21h. The set drive code function in turn calls two internal functions to set the DOS Current Directory Structure (CDS) could call INT 21h AX=1211h and set drive calls INT 21h AX=1217h.

Both functions call select disk sets the carry flag indicating failure. select disk 0E *still* sets the value of LASTDRIVE. At first it seems that we could pass any old drive number into INT 21h function 0Eh and then read back the value of LASTDRIVE. In Listings 2-1 through 2-6, the code that we called INT 21h function 19h to get the current drive was strictly necessary, since all we really wanted was LASTDRIVE's return value. Of course, you don't want to pass in an arbitrary *valid*

drive number because the DOS [illegible] do what you say and change to that drive [illegible] not be a desirable side effect for a LASTDRIVE utility. However, passing [illegible] number would work great.

This makes sense [illegible] the Microsoft MS-DOS [illegible] Reference didn't say anything [illegible] returning the value of LASTDRIVE [illegible]. In retrospect, the DOS documentation was pretty clear [illegible] implementation of INT 21 function 0Eh is supposed to do. It shouldn't [illegible] necessary to look at the code to realize this. Nonetheless, seeing the actual code does help make it clearer.

It should be possible [illegible] INT 21 function 0Eh [illegible] rather than as a Select Disk function. Sure enough, calling select disk 0FFh [illegible] works.

You can learn some other interesting [illegible] about this DOS function [illegible] the code in Listing 2-8 [illegible] For example [illegible] Listing 2-8 keeps [illegible]

Note in Listing 2-8 [illegible] LASTDRIVE to AL but also sets the [illegible] DOS [illegible] CURRDRIVE. The DOS Get Current Disk function (INT 21h function 19h) [illegible] value to pass to INT 21h function 0Eh does nothing more than return the value of [illegible] AL:

```
-u fdc9:4c64
FDC9:4C64 A03603        MOV     AL,[0336]       ; DOS_DS:0336
FDC9:4C67 C3            RET
```

If you are wondering about [illegible] INT [illegible] Listing 2-8 [illegible] select disk function called on select disk 0Eh [illegible] AL [illegible] produced by function 19h [illegible] based drive number just like [illegible] 0Eh.

[illegible] DOS [illegible] There are [illegible] But in any case [illegible] 0Eh [illegible] DOS [illegible] CURRDRIVE [illegible] for what [illegible] DOS [illegible] LASTDRIVE.

Let's look at [illegible] DOS [illegible] DOS:[illegible] CURRDRIVE [illegible] 0336 [illegible] First, some Microsoft software [illegible] DOS data [illegible] DOS data segment [illegible] Chapter [illegible] the location of [illegible] DOS [illegible] CURRDRIVE [illegible] located within [illegible] of the DOS [illegible] the Swappable Data Area (SDA) [illegible] DOS [illegible] INT 21 AX=5D06 [illegible] pointer to the SDA [illegible] 0320 [illegible] CURRDRIVE is located [illegible] SDA [illegible] INT 21h AX=5D06 in the appendix reveals [illegible] DOS keeps the current drive value at offset [illegible] the SDA. All is right with the world.

What about LASTDRIVE? Listing 2-8 shows this to be at 0142 0047 [illegible] is actually a [illegible] larger [illegible] DOS data segment [illegible] INT 21h AH=52h [illegible] 0142 0026 [illegible] DOS keeps LASTDRIVE [illegible] to write a program [illegible] undocumented DOS to retrieve LASTDRIVE [illegible] the information you're looking for.

Using the Interrupt List

So LASTDRIVE is just a byte stored at offset 21h by the address returned from INT 21h function 52h. We found this information by disassembling DOS. But there's another, easier way to find out this kind of information: from Ralf Brown's Interrupt List! When you leaf through Ralf's appendix to his book, you'll find DOS's internal location for LASTDRIVE in the middle of SysVars, or the List of Lists. However, it moved around a lot before DOS 4.

Table 2-1: Movement of LASTDRIVE Within SysVars

Offset	Size	Description	
10h	BYTE	number of logical drives in system	DOS 2.x
18h	BYTE	value of LASTDRIVE command in CONFIG.SYS (default 5)	DOS 3.0
21h	BYTE	value of LASTDRIVE command in CONFIG.SYS (default 5	DOS 3.1 - 3.3
21h	BYTE	value of LASTDRIVE command in CONFIG.SYS (default 5	DOS 4.x +

SysVars (or the DOS internal variable table) is probably the most important undocumented DOS data structure, and INT 21h function 52h, which returns in the ES:BX register pair a pointer to SysVars, is the most important undocumented DOS function.

Note from Table 2-1 how the offset of the LASTDRIVE field within the DOS internal variable table changed from DOS 2.0 to DOS 3.0 to DOS 3.1. Disassembling just one version of DOS does not, of course, uncover this problem. This sort of undocumented DOS behavior is just what our programs have to deal with. What the offset will be in future versions is anyone's guess, and that, of course, is the whole problem with using undocumented DOS.

In future versions of DOS, the LASTDRIVE field might even disappear, breaking whatever programs depend upon its presence. The only comfort is that, should SysVars change radically, not only will our own programs start to fail, but practically all important Microsoft software will break, too.

For example, the DOSMGR.SYS device driver, crucial to the operation of Windows Enhanced mode, depends on finding LASTDRIVE at SysVars-21h (see Figure 1-10), which is one reason why Windows requires DOS 3.1 or higher and specifically does not run on DOS 3.0. The reluctance of key products, Microsoft software such as Windows 3.x or the internal structure of DOS might make this DOS structure unlikely to change. However, that perhaps is too much to hope for in a large company, where members of different groups exist and may not talk with each other (see the discussion of Chinese Walls in Chapter 1).

I mentioned the changes to the position of LASTDRIVE within SysVars, and if you look at the appendix entries for INT 21h function 52h, massive changes throughout SysVars as a whole. (Note the use of the word *undocumented* in INT 21h function 52h, isn't it?)

```
INT 21 - DOS 2+ internal - GET SYSVARS
AH = 52h
Returns:
    ES:BX -> DOS SysVars
```

From DOS 2.0 forward, this function has been as stable as any documented DOS function. Even standard DOS environments, such as the DOS boxes in OS/2 2.0 and Windows NT, support it (see Chapter 4).

No Magic Numbers

Because the SysVars structure is so central to DOS programming, many books on the subject end up using INT 21h function 52h somewhere in their sample source code. However, because of their authors' possibly guilty feelings about using undocumented DOS in the first place, sometimes these

books simply leave the code unexplained. For example, in the normally well commented Turbo Pascal source code in an extremely useful book on LAN programming, Craig Chaiken's *Run print at a LAN*, the following code appears without any explanation:

```
regs.ah := $52;
intr($21, regs);
ofs := regs.bx + $22;
seg := regs.es;
while mem[seg:ofs] <> $ffff do
    .
```

Here, the author is using INT 21h function 52h to get a pointer to SysVars and then using offset 22h in SysVars to get a pointer to the linked list of device drivers that DOS maintains. Obviously, the author needs to find some device in memory. What's so hard about that? Nothing, except the code appears out of the blue, with no comment or explanation, like a small piece of magic. The code might as well have been commented "and then a miracle occurs" or even "you are not expected to understand this."

> *You are not expected to understand my code.* — UNIX. The canonical comment accompanying something magic or too complicated to bother explaining properly. From an infamous comment in the context switching code of the V6 UNIX kernel. Eric Raymond (ed.), *The New Hacker's Dictionary*, 1991

Let's look at INT 21h function 52h but not explain what it does seems far worse than using an undocumented call in the first place. As used above, 52h and 22h and even 1111h appear to be random magic numbers. Let's see if we can't completely demystify INT 21h, tamer of 52h.

You can try out this function without even writing a program by using the DOS DEBUG utility. First assemble the DOS call and execute it:

```
C:\UNDOC2>debug
-a
775A:0100 mov ah, 52
775A:0102 int 21
775A:0104 nop
775A:0105
-g 104
AX=5200  BX=0026  CX=0000  DX=0000  SP=FFEE  BP=0000  SI=0000  DI=0000
DS=775A  ES=028E  SS=775A  CS=775A  IP=0104   NV UP EI PL NZ NA PO NC
775A:0104 90            NOP
```

The register dump shows that, in this sample DEBUG session, ES:BX points to 028E:0026.

```
-d es 0026
028E:0020                                F0 75 8E 02 98 00 8E 02-A6 01          .u..  .
028E:0030  70 00 6E 01 70 00 00 02-00 00 49 0C 00 00 EE 0C   p.n.p .....I.  ..
028E:0040  00 00 60 0A 00 00 03 05-12 00 F4 09 04 80 99 15     `  ...  ..
028E:0050  9F 15 4E 55 4C 20 20 20-20 20 00 90 43 17 8E 02     NUL     .C
028E:0060  47 17 8E 02 47 17 8E 02-43 17 8E 02 43 17 8E 02   G   G   C   C .
```

Aside from the NUL string at offset 0052, it's difficult to find our way around here. But if we hold the SysVars format (again, see INT 21h AH=52h in the Appendix) over the DEBUG dump, it all makes sense. Formatting the first four bytes, F0 75 8E 02, as a DWORD pointer, for example, comes out as 028E:75F0, a pointer to the first Disk Parameter Block (DPB):

Offset	Size	Description	
00h	DWORD	first Disk Parameter Block	028E:75F0
04h	DWORD	first of DOS file tables	028E:0098
08h	DWORD	pointer to CLOCKS device driver	0070:0A44
0Ch	DWORD	pointer to CON device driver	0070:0A64

Offset	Size	Description	
10h	WORD	max bytes/block	0200
12h	DWORD	first disk buffer	0C49:0000
16h	DWORD	Current Directory Structures	0CEE:0000
1Ah	DWORD	pointer to FCB table	03A0:0000
1Eh	WORD	number of protected FCBs	0000
20h	BYTE	number of block devices	03
21h	BYTE	LASTDRIVE	05
22h	18 BYTEs	actual NUL device driver header	next dev 09E4:0012 attr 8004h strat 1599h intr 159Fh name 'NUL '
34h	BYTE	number of JOINed drives	00

We now see that the Turbo Pascal code quoted earlier was adding 22h to the value returned from INT 21h function 52h so that it could get a pointer to the NUL device, which is the head of DOS's device chain. This is one of the most popular uses of INT 21h function 52h, but clearly SysVars holds many other goodies, which is why it has also been called the DOS List of Lists.

Let's look at the value of the LASTDRIVE field in SysVars since LASTDRIVE=E: which is the default, even if CONFIG.SYS does not include a LASTDRIVE statement.

Having seen a little more of what SysVars looks like, we can now retrace our steps in building the LASTDRV utility this time using INT 21h function 52h and the LASTDRIVE field within the DOS internal variable table. You may be thinking that this is a little extra because we already know how to get hold of LASTDRIVE using a completely safe and documented function that doesn't change with each new version of DOS. However, we will see later on that using the undocumented method to get LASTDRIVE is actually more reliable than using the documented function 08h, as it avoids the opening of some interesting possibilities. After all, Quarterdeck must have *some* reason for using function 52h rather than function 08h.

Undocumented DOS Calls from Assembly Language

The small assembly language program in Listing 2-9 shows one how to translate the reference material on DOS function 52h into SysVars into a working version of LASTDRIVE:

Listing 2-9: LASTDRV2.ASM

```
; LASTDRv2.ASM -- uses undocumented DOS

        assume cs:_TEXT, ds:_DATA, ss:_STACK

_STACK  segment para stack 'STACK'
_STACK  ends

_DATA   segment word public 'DATA'
msg     db      'LASTDRIVE='
dletter db      ?
        db      0dh, 0ah, '$'
_DATA   ends

_TEXT   segment word public 'CODE'

        public  _lstdrv

_lstdrv proc    far
        push    si
        push    bx
        push    cx

        mov     si, 18h         ; assume DOS 3.0
```

```
        mov     ax, 3306h       , Get (genuine) MS-DOS version
        xor     bx, bx          , Don't know if func supported, so zero BX
        int     21h
        or      bx, bx          , Is BX still zero, or did it get changed?
        jz      do_2130         , Not supported, so call 21/30
        ; 21/3306 returns major=BL, minor=BH
        , move into AX to make appear as if returned from 21/30
        mov     ax, bx
        jmp     short got_vers
do_2130:
        mov     ax, 3000h       ; Get MS-DOS version number
        int     21h             , major=AL, minor=AH
got_vers:                       , either did 21/3306 or 21/30
        cmp     al, 2
        jl      fail            ; Requires DOS 2+
        jne     dos3up          ; DOS 3+
        mov     si, 10h         , DOS 2.x
        jmp     short get
dos3up: cmp     al, 3
        jne     ofs21
        and     ah, ah          , DOS 3.0
        jz      get
ofs21:  mov     si, 21h         , DOS 3.1+, DOS 4+

get:    mov     ah, 52h         ; Get SysVars
        xor     bx, bx          , Zero out ES:BX so we can check
        mov     es, bx          ,   for NULL after INT 21h
        int     21h             ; List=ES:BX
        mov     cx, es
        or      cx, bx          ; Is ES:BX NULL?
        jz      fail            ; Function 52h not supported

        mov     al, byte ptr es:[bx+si]
        xor     ah, ah          ; return LASTDRIVE in AX
        jmp     short fini

fail:   xor     ax, ax          ; return 0 in AX
fini:   pop     cx
        pop     bx
        pop     si
        ret
_lstdrv endp
main    proc    near
        mov     ax,  DATA
        mov     ds, ax

        call    _lstdrv
        and     ax, ax          , test for failure
        jz      done

        mov     bl, al          , save LASTDRIVE in BL
        add     al, ('A'   1)   , convert LASTDRIVE to drive letter
        mov     dletter, al     ; insert into string

        mov     ah, 9           ; Display String
        mov     dx, offset msg
        int     21h

done:   mov     ah, 4Ch         ; Return to DOS
        mov     al, bl          ; exit code
        int     21h
main    endp
_TEXT   ends
        END     main
```

He must also contain boring documented DOS code for displaying output and for exiting to DOS. So the really interesting code and all of the undocumented DOS is in the slightly convoluted steps we need to go through in the following pseudocode

```
offset = 10h,
ver    = DosVersion(),
if (ver major < 2) return failure,
else if (ver major =  2)                    offset  = 10h,
else if (ver major =  3 or ver minor =  0) offset  = 21h,
ListOfLists    = GetListOfLists(),
if (ListOfLists == NULL) return failure,
else                     return ListOfLists[offset];
```

The goal of the various DOS version number tests is to put the correct location of LASTDRIVE into the SI register, so that it can be added to the base address of SysVars that we get back from DOS undocumented function 52h. The SI register is preloaded with the offset of LASTDRIVE for DOS 3.0, in a somewhat foolish attempt to reduce the large number of IMPs.

DOS Versionitis

Now, as you will see, DOS versions greater than 3.0 we store 21h into the offset. Usually when testing the DOS version number it is enough to test for equality or *greater than or equal to* the highest known version number at the time (3.0). Unfortunately for example version 4.0 introduced a few changes and expansions to the SysVars structure as DOS 3.0. For example *PC Magazine* has published a program that check the DOS version with the JE instruction rather than with JB or JA. Unfortunately this program failed when tested even on Microsoft computers with a new version of DOS. Perhaps its even true of applications even those that use no undocumented calls at all were not correctly updated when DOS version numbers Microsoft introduced by SET VER command.

In general, all DOS versions before (but not including) 3.0 as one can observe we are assuming that, for example DOS 6.0 stores LASTDRIVE in the same place as DOS 3.3 which in fact it does. When testing for DOS versions greater than 3.0 we can make this assumption or we can take the more conservative approach of letting the program make its own decisions about MS-DOS.

Now you may not know what the conservative approach is absolutely necessary. As an example of the second method, this book contained code to access the DOS Swappable Data Area. The obvious INT 21 AX=5D06h code DOS 3.x and INT 21 AX=5D0Bh under DOS 4.0 *and higher* gives incorrect results for example DOS 5.0. Microsoft reverted to the DOS 3.0 style AX=5,300h although it was a bit late for *Undocumented DOS* that broke tasks under DOS 5.0.

Unfortunately there is a further problem with using undocumented DOS. If your application uses undocumented functions or undocumented structures, perhaps you should use — rather than to test DOS version numbers. On the other hand there are several double checks your program could perform so that it could simply ignore the underlying or confusing sands of DOS internals. You will see such double check later in this chapter.

When testing DOS version numbers remember that DOS function 30h conventionally returns the *major* version number in AL and the minor version number in AH. Also remember that a version number such as 3.1 is actually 3.10 and not 3.1. DOS 3.10 the minor version number is AH is neither 01h nor 10h but 0Ah.

The most important point about the DOS version number though is that it might be *wrong*. The SET VER command lets the DOS version number returned from INT 21h function 30h to be set to any value by application. Lasso. You can see why applications are being faked out by typing SET VER at the DOS prompt. For example in DOS 5.0 and 6.0 SET VER tells WINWORD.EXE and EXCEL.EXE that we're in real mode DOS stubs of these Windows programs that they are running under DOS 4.10. It's a sick world out there!

It is important to remember that SETVER changes nothing except the version number reported by INT 21h function 30h. SETVER doesn't change any other aspect of DOS behavior. WINWORD.EXE is still running under DOS 6.0, for example, not *emulating* a version upgrade. (DOS 4.10 is an interesting exception. This well-mannered, backwards compatible, hacked-up Microsoft OS has the undocumented GetAppCompatFlags function in Windows. This function changes the actual behavior of Windows on a per-application basis; see *Undocumented Windows*, Chapter 5.)

Because SETVER just changes the INT 21h function 30h version number, not the actual structure of DOS, utility programs that rely on undocumented DOS data to get the true DOS version number (Peter Norton's DOS 6.0 and higher provides a documented way to do this: INT 21h function 3306h returns the true DOS version number in BX. This function also reports on whether DOS is in ROM and whether DOS=HIGH.)

There's one complication here. INT 21h function 3306h is supported only in DOS 5.0 and higher. But you don't know whether you are actually running under DOS 5.0 or higher unless you call this function. One of the authors once wrote a piece of code in which he first called INT 21h AH=30h and then, if it reported the version number 5.0 or greater, he called INT 21h AX=3306h. This was unreliable, stupid because the whole point is that INT 21h AH=30h may have been SETVER'ed to erroneously report some version number less than 5.0. But this means you must call INT 21h AX=3306h without knowing first whether that function is actually supported. And you can't rely on the carry flag being set if you call an unsupported INT 21h function.

As section 2.9 of MSDOS2.9 (MSDOS2.ASM) and 2.10 of MSDOS4.0 (the solution is to preload BX with zero before calling INT 21h AX=3306h. If the function isn't supported, BX will still be zero after issuing the INT 21h. If the function is supported, BX will be changed to some DOS version number.

Who would have thought that something as simple as getting the DOS version number would be so complicated? But it gets worse. The DOS box in OS/2 2.1 reports a DOS version number of 20.40 in OS/2 2.0 and 20.10. Yet, as we'll see in Chapter 4, this version number generally behaves like DOS 5.0.

Digital's DR DOS 5.0 and 6.0 report the DOS version number as 5.x. Chapter 4 shows that there are undocumented DR DOS functions that return an actual DR DOS version code rather than the simulated DOS version number.

The lesson here is that you should do whatever you can to minimize your dependence on specific versions of DOS because the DOS version number is a complete mess.

Accessing SysVars

At any rate, as you can see in the following example code, once SETVER is out of the picture, the version of DOS the program is running under can be easy:

```
mov ah, 52h
int 21h
mov al, byte ptr es:[bx+xx]
xor ah, ah
```

Actually, in LANDRV2.ASM the code is slightly more complicated than this because we have taken the precaution of verifying that undocumented INT 21h function 52h is really supported by checking that the pointer in ES:BX is not NULL. The ES:BX register pair is loaded with NULL prior to invoking INT 21h so that, if you're running some unusual DOS environment that doesn't support this function, ES:BX will at least hold a reasonable value we can test for:

```
mov ah, 52h
xor bx, bx
mov es, bx
int 21h
mov cx, es
or cx, bx
jz fail
```

Note, however, that the code doesn't check whether INT 21h AH=52h set the carry flag (CF). Unless undocumented specifically says that a function sets or clears CF, the state of CF is undefined. The entry for INT 21h function 52h in the appendix to this book says nothing about CF. Thus, far from being a careful, precision-checking CF in fact would be a perfect example of relying on *undefined* behavior. Using undocumented DOS is completely different from relying on undefined behavior.

Although this version of LASTDRV looks completely different from the version that used only documented DOS calls, the result is similar. This version also displays and returns the value of LASTDRIVE. The difference is that now you're getting information straight from the horse's mouth by examining the DOS internal variable table.

Undocumented DOS Calls from C

This book has spent so much time on the LASTDRV utility and on various ways of performing DOS calls from C that you would think there would be nothing more to say. However, the following version of LASTDRV (Listing 2-10) introduces a number of important topics, including the use of far pointers in C, the MK_FP() macro, testing the DOS version number, and using int86x() rather than int86().

Listing 2-10: LASTDRV4.C

```
/* LASTDRV4.C -- uses undocumented DOS */

#include <stdlib.h>
#include <stdio.h>
#include <dos.h>

#ifndef MK_FP
#define MK_FP(seg,ofs) \
    ((void far *)(((unsigned long)(seg) << 16) | (ofs)))
#endif

main()
{
    union REGS r;
    struct SREGS s;
    unsigned char far *sysvars;
    unsigned lastdrv_ofs;
    unsigned lastdrv;

    /* Try to get DOS version from 21/3306 call first, since
       this returns the true DOS version number.  The 21/30 call
       used to set _osmajor, _osminor can be changed on a
       per-app basis with the DOS SETVER command  */
    r.x.ax = 0x3306;
    r.x.bx = 0;
    int86(0x21, &r, &r);
    /* See if 21/3306 actually supported.  This is tricky because
       the behavior of unsupported calls is undefined  */
    if (r.x.bx != 0)   // BX has changed: func must be supported
    {
        _osmajor = r.h.bl;
        _osminor = r.h.bh;
        printf("21/3306 returns %u.%02u\n", _osmajor, _osminor);
    }

    /* Get offset for LASTDRIVE within SysVars */
    if (_osmajor < 2)                       return 0;
    else if (_osmajor == 2)                 lastdrv_ofs = 0x10;
    else if (_osmajor == 3 && _osminor == 0) lastdrv_ofs = 0x1b;
    else                                    lastdrv_ofs = 0x21;

    /* Get DOS Lists of Lists */
    r.h.ah = 0x52;
    segread(&s);
```

```
    s.es = r.x.bx = 0;
    int86x(0x21, &r, &r, &s);
    /* make sure Function 52h is supported */
    if (! s.es && ! r.x.bx)
        return 0;
    sysvars = (unsigned char far *) MK_FP(s.es, r.x.bx);

    /* Get LASTDRIVE number */
    lastdrv = sysvars[lastdrv_ofs];

    /* OS/2 DOS compatibility box sets LASTDRIVE to FFh */
    if (lastdrv == 0xFF)
        return 0;

    /* Print LASTDRIVE letter */
    fputs("LASTDRIVE=", stdout);
    putchar('A' - 1 + lastdrv);
    putchar('\n');

    /* return LASTDRIVE number to DOS */
    return lastdrv;
}
```

If you contrast LASTDRV4.C with the earlier versions that used only documented DOS calls you will notice a number of significant differences. Rather than call INT 21h function 30h to get the DOS version number as the assembly language version of LASTDRV.C now uses the global variables (or near and far pointers) provided by most C compilers for the PC. The Microsoft C, Watcom C 386, and MetaWare High C 386 SETDEFH.H declares these variables in Borland C++ as far pointers are declared in DOS.H. It is important to remember that in DOS 3.3 for example the word at 0:430 lies mainly not 3 and not 0x30. Just note that even with compact and medium memory models you must still call INT 21h function 3306h if you're running under a version of DOS that supports this function as the return value to possibly change (minor) and (minor).

Because DOS function 52h returns an addressed SysVars in ES:BX and because most 80x86 classes handle segment registers such as ES automatically use most 80x86 and struct SREGS variables to pass and segment registers *into* function 52h so segment is being to closer. Until matter what value the struct SREGS holds before calling int 86x. Note however a good habit to call the segment to not on to load the struct SREGS variables example case because sometimes to move your code to a protected mode DOS extender it will be easier that you never load the segment registers with garbage values even if these registers are seemingly not used.

Because SysVars is part of DOS and not located inside your program it must be addressed with a four byte far pointer. The C variable doesn't is needed to find this address and is declared as *char far ** rather than as *char **. This allows you to peek at and poke DOS internal variables easily even from a C program that otherwise uses only two byte near pointers.

After DOS function 52h has returned the address of SysVars in ES:BX on 80x86 systems ES and BX. How do you move these into *far pointer*? LASTDRV4.C uses the macro MK_FP which as its name implies makes a far pointer from a segment and an offset. This handy macro is provided in the DOS.H header file with Borland C++ but unfortunately not with Microsoft C. LASTDRV4.C uses the C preprocessor to define a MK_FP macro if one is not already present. While the definition of MK_FP makes it appear as if it is performing a shift left. Any good C compiler for the PC turns this code

```
void far *fp = (void far *)(((unsigned long)(seg) << 16)   (ofs));
```

into this

```
mov ax, _seg
mov dx, _ofs
mov word ptr _fp, dx
mov word ptr _fp+2, ax
```

You can recompile your C compiler's output by compiling with the -Ze or -Ze switch in Microsoft C, for example, or the -N switch in Borland C++.

Rather than use the MK_FP macro in Microsoft C, you could also use the following construct:

```
FP_SEG(doslist) = s.es;
FP_OFF(doslist) = r.x.bx;
```

FP_SEG and FP_OFF are two other important macros for PC systems programming in C. Whereas MK_FP constructs a far pointer from a segment and an offset, FP_SEG and FP_OFF perform the opposite operation. FP_SEG extracts the segment of a far pointer, and FP_OFF extracts the offset. Microsoft's versions of FP_SEG and FP_OFF are C lvalues and can therefore be assigned to.

The C version of LASTDRV also does a bit more work than the assembly language version. Before accessing the LASTDRIVE byte, LASTDRV4.C checks to see if LASTDRV is 0FFh, checks the version number of DOS, and ID DOS compatibility box (also known as the penalty box) uses for the LASTDRIVE byte. The latest version of SysVars, a program running in this compatibility box, tells us not to refer DOS 5.0 to 6.10 as you might think the program should simply fail if you ask for DOS versions lower than 5.0. Support for undocumented DOS has improved in each version of the DOS box, so there will be less reason to distinguish between versions from this simulated DOS environment. For instance, the DOS 5.0 and DOS 6.22 boxes, which misreport as DOS version 20.10, do provide proper support for LASTDRIVE and for most other fields in SysVars, as well. It is worth noting that although the DOS 5.0 and 6.22 boxes report the double-digit DOS 20.10, the DOS 7.0 compatibility box closely resembles DOS 5.0 with SETVER loaded. See Chapter 4 for details of DOS emulation in DOS 7.

What, No Structures?

A common question that begins the discussion of LASTDRV4.C is "Where are the structures?" You need only look at the .ASM files for DOS Interrupt 52h and SysVars in the appendix to see that all these offsets will be easier to express and work with as C structures. You might even ask why this book doesn't provide an UNDOC.H include file.

The reason we do not have an UNDOC.H include file for you is that programs that use undocumented DOS can't survive from one DOS version to the next. An UNDOC.H file could be an invitation to write software that uses undocumented DOS calls. We don't want to promote undocumented DOS as yet another application programming interface (API) consisting of some standard new functions and data structures.

There is a valid need, however, to provide software using data structures in undocumented DOS programming. This becomes clear as we discuss the next program, LASTDRV5.C (Listing 2-11), which uses C structures to represent much of SysVars.

Listing 2-11. LASTDRV5.C

```
/* LASTDRv5 ( */

#include <stdlib.h>
#include <stdio.h>
#include <dos.h>

#ifndef MK_FP
#define MK_FP(seg,ofs) \
    ((void far *)(((unsigned long)(seg) << 16) | (ofs)))
#endif

#pragma pack(1)

#define SYSVARS_DECR        12

typedef struct {
    unsigned shareretrycount, shareretrydelay;
    void far *currdiskbuff;
```

```
    void near *unreadcon;
    unsigned mcb,
    void far *dpb, far *filetable;
    void far *clock, far *con;
    union {
        struct {
            unsigned char numdrive,
            unsigned maxbytes;
            void far *first_diskbuf;
            unsigned char nul[18];
            } dos2;
        struct {
            unsigned char numblkdev,
            unsigned maxbytes;
            void far *first_diskbuf, far *curdir;
            unsigned char lastdrive;
            void far *stringarea,
            unsigned size_stringarea;
            void far *fcbtab,
            unsigned fcb_y,
            unsigned char nul[18];
            } dos30,
        struct {
            unsigned maxbytes;
            void far *diskbuff, far *curdir, far *fcb;
            unsigned numprotfcb,
            unsigned char numblkdev, lastdrive,
            unsigned char nul[18],
            unsigned numjoin,
            } dos31;    /* and higher */
        } vers;
    } SysVars,

main()
{
    union REGS r;
    struct SREGS s,
    SysVars far *sysvars,
    unsigned lastdrive;
    /* Try 21/3306 first */
    r.x.ax = 0x3306,
    r.x.bx = 0,
    int86(0x21, &r, &r);
    if (r.x.bx != 0)
    {
        _osmajor = r.h.bl;
        _osminor = r.h.bh,
    }
    /* No SysVars in DOS 1.x */
    if (_osmajor < 2) return 0;
    /* Get SysVars */
    r.h.ah = 0x52,
    segread(&s),
    s.es = r.x.bx   0,
    intdosx(&r, &r, &s);
    if (! s.es && ! r.x.bx)
        return 0;
    sysvars = (SysVars far *) MK_FP(s.es, r.x.bx - SYSVARS_DECR),
    /* Get LASTDRIVE value, depending on DOS version */
    if (_osmajor == 3 && _osminor == 0)
        lastdrive = sysvars->vers.dos30.lastdrive,
    else if (_osmajor == 2)
        lastdrive = sysvars->vers.dos2.numdrive;
    else
```

```
    lastdrive = sysvars->vers dos31 lastdrive;
    /* print LASTDRIVE letter, return LASTDRIVE number */
    printf("LASTDRIVE=%c\n", 'A' - 1 + lastdrive);
    return lastdrive;
}
```

From looking over struct SysVars, you should understand why this is sometimes called the List of Lists. Most of the fields are just pointers to other data structures, including the list of DOS Memory Control Blocks, the list of Drive Parameter Blocks, the DOS device chain, and the File Control Block tables. Furthermore, in a complete SysVars structure, those other fields would each also—for example, FCB_tar * or DPB far *—rather than void far *.

The struct SysVars uses a C union to manage the differences between DOS versions. Unions help represent the changes that each version of DOS brought to SysVars. Each component of a C union is allocated storage starting at the beginning of the union, and the size of a union is the amount of storage necessary to represent its largest component. In other words, as in a variant record in Pascal, the components are overlaid. In the union vers within struct SysVars, the same block of memory can be vers.v2, vers.dos2_x, vers.dos30, or vers.dos31.

The code that reads #pragma pack 1 is essential. By default, C compilers for the PC align structures on word or two-byte boundaries. For this C structure to correspond exactly with the layout of the DOS internal variable table, you need to pack the structure on byte boundaries. Otherwise, an unsigned char followed by an unsigned short would occupy four bytes, not three, and the structure would not reflect DOS's internal variable table.

Note that the program creates not a struct SysVars but a far *pointer* to a struct SysVars. The memory for the structure already exists inside DOS. Also, to get at some of the useful variables located just before the pointer returned from INT 21h function 52h, the program uses ES:BX-12 rather than ES:BX.

This example demonstrates a fundamental problem with using data structures when working with undocumented DOS. Structures are unstable. The C compiler, seeing a reference such as dosist.vers.dos31.lastdrive, simply turns this reference into an offset into dosist. The *compiler* computes these offsets. The program itself does not compute the offsets while it is running, so the offsets don't change at run time based on conditions such as different versions of an operating system.

You could use some of the sophisticated data-structure features of C++ to create a LastDrive class or struct that responds to the DOS version number. When working with undocumented DOS data structures, programmers often wish the system had methods. One benefit of C++ is its ability to implement such wishful thinking by creating classes that manage and hide the complexity of underlying structures.

When using only one or two fields from an undocumented DOS data structure, however, and when the location of the fields within the structure differs from one DOS version to the next, it is best *not* to use structures at all but to compute offsets instead. Structures may be self-documenting, but they're inflexible. Here's how to use the conditional expression in Listing 2-11 to extract the LASTDRIVE byte from the appropriate component of the union vers in struct lastDrive. Note how much simpler it is when you use offsets:

```
if (_osmajor == 3 && _osminor == 0) lastdrv_ofs = 0x18;
else if (_osmajor == 2)             lastdrv_ofs = 0x10;
else                                lastdrv_ofs = 0x21;
lastdrv = dosist[lastdrv_ofs];
```

or

```
lastdrv_ofs = (_osmajor == 3 && _osminor == 0) * 0x18
            + (_osmajor == 2) *                  0x10
            /* otherwise */                      0x21 ;
lastdrv = dosist[lastdrv_ofs];
```

or the even more compact C expression which also uses the C ternary conditional operator, in the next version of this utility, LASTDRV6.C in Listing 2-12.

Listing 2-12: LASTDRV6.C

```
/* LASTDRV6.C */

#include <stdlib.h>
#include <stdio.h>
#include <dos.h>

#ifdef __TURBOC__
#define ASM asm
#elif defined(_MSC_VER) && (_MSC_VER >  600)
#define ASM _asm
#else
#error Requires inline assembler
#endif

unsigned _dos_lastdrive(void)
{
    unsigned char far *sysvars;

    /* try 21/3306 first */
    ASM mov ax, 3306h
    ASM xor bx, bx
    ASM int 21h
    ASM or bx, bx
    ASM jz osmajmin_ok
    ASM mov byte ptr _osmajor, bl
    ASM mov byte ptr _osminor, bh

osmajmin_ok:
    if (_osmajor < 2)
        return 0;

    ASM mov ah, 52h
    ASM int 21h
    ASM mov word ptr sysvars+2, es
    ASM mov word ptr sysvars, bx
    return sysvars[(_osmajor == 3 && _osminor == 0) ? 0x10
                   (_osmajor >= 3) ?                  0x10
                   /* otherwise */                    0x21];
}

main()
{
    unsigned lastdrive = _dos_lastdrive();
    if (lastdrive == 0xFF)
        return 0;
    fputs("LASTDRIVE=", stdout);
    putchar('A' - 1 + lastdrive);
    putchar('\n');
    return lastdrive;
}
```

The other item of interest in LASTDRV6.C is the use of inline assembly within the function dos_lastdrive. The inline assembler language often seems like an invitation to produce excessively inline code. C programmers choosing inline assembly language for the first time seem to forget all about subroutines. Especially when working with the combination of undocumented DOS and inline assembler, you should remember to use subroutines. But also remember to use a strategy to preserve the DI, SI, DS, ES, and SP registers. The inline assembler in dos_lastdrive only changes AX, BX, and ES so you're in luck here. The name was chosen to conform to the Microsoft C naming convention: dos_getdrive, dos_setdrive, etc.

Undocumented DOS Calls from Turbo Pascal

Turbo Pascal programs that make undocumented DOS calls are similar to those that make documented calls, except that, as with assembly language and C, such programs need to be especially aware of the version of MS-DOS under which they are running. The following program, LASTDRV2.PAS (Listing 2-13), uses the function DosVersion, added in Turbo Pascal 5.0.

Listing 2-13: LASTDRV2.PAS

```
{ LASTDRV2.PAS }

program LastDrv;
uses Dos;
var
    r           registers,
    lastdrv_ofs : word,
    lastdrive   : word,
    vers        : word,

begin
    { determine offset of LASTDRIVE within SysVars }
    lastdrv_ofs := $21,
    vers := DosVersion,
    case lo(vers) of
        0 : Halt(0); { DOS 1 }
        2 : lastdrv_ofs := $10,
        3 : if hi(vers) = 0 then lastdrv_ofs := $18;
    end,

    { Get pointer to SysVars }
    with r do begin
        ah := $52,
        es := 0; bx := 0,
        MsDos(r),
        if (es = 0) and (bx = 0) then
            Halt(0),
        lastdrive := Mem[es:bx+lastdrv_ofs],
    end,

    if lastdrive = $ff then
        Halt(0),

    { Print LASTDRIVE letter, return LASTDRIVE value }
    Writeln('LASTDRIVE ', Chr(Ord('A') - 1 + lastdrive)),
    Halt(lastdrive),
end
```

If you are working with a version of Turbo Pascal earlier than 5.0 and don't have the DosVersion function, it is easy to write your own:

```
function DosVersion : Word;
var
    r : registers,
begin
    with r do begin
        ax := $3000;            {should call $3306 too!}
        MsDos(r),
        DosVersion := ax;
    end,
end,
```

Note that LASTDRV2.PAS uses the predefined Turbo Pascal array Mem[] to peek at SysVars. Mem[], MemW[], and MemL[] map onto the first megabyte of physical memory in the machine; you access them with a segment:offset index such as Mem[seg:ofs].

Rather than peek at a raw physical memory address with Mem[], you could use a data structure. Just as structures and unions can be used when making undocumented DOS calls from C, so variant records can be used from Turbo Pascal, as shown in LASTDRV3.PAS, Listing 2-14.

Listing 2-14: LASTDRV3.PAS

```
{ LASTDRV3.PAS }
program LastDrv;
uses Dos;
type
    Dos20 = record
        numdrives : Byte;
        maxbytes : Word;
        first_diskbuff : Longint;
        nul : array [1..18] of Byte;
    end;
    Dos30 = record
        numblkdev : Byte;
        maxbytes : Word;
        first_diskbuff : Longint;
        currdir : Longint;
        lastdrive : Byte;
        stringarea   Longint;
        size stringarea   Word;
        fcbtab   Longint;
        fcb_y : Word;
        nul : array [1..18] of Byte;
    end;
    Dos31 = record      { DOS 3.1 and higher }
        maxbytes   Word;
        diskbuff : Longint;
        currdir   Longint;
        fcb   Longint;
        numprotfcb   Word;
        numblkdev : Byte;
        lastdrive   Byte;
        nul : array [1  18] of Byte;
        numjoin   Word;
    end;
    ListOfLists = record
        shareretrycount : Word;
        shareretrydelay : Word;
        currdiskbuf : Longint;
        unreadcon   Word;
        mcb   Word;
        dpb   Longint;
        filetable : Longint;
        clock   Longint;
        con   Longint;
        case Word of
            20   (dos20   Dos20),
            30   (dos30   Dos30),
            31   (dos31 . Dos31),
end;
var
    lastdrive : Word;
function GetLastDrive : Word;
var
    doslist : ^ListOfLists;
    r : registers;
    vers : Word;
```

```
begin
    { Get pointer to SysVars }
    with r do begin
        ah    $52,
        es    0, bx    0,
        MsDos(r),
        if (es = 0) and (bx = 0) then begin
            GetLastDrive := 0;
            Exit,
        end,
        doslist := Ptr(es, bx - 12);
    end,
    { LASTDRIVE offset depends on DOS version }
    GetLastDrive  = doslist^ dos31 lastdrive,

    vers    DosVers on
    case Lo(vers) of
        0   GetLastDrive := 0; { DOS 1 }
        2   GetLastDrive := doslist^ dos20 numdrives;
        3 : if Hi(vers) = 0 then
                GetLastDrive  = doslist^ dos30 lastdrive,
    end,
end,

begin
     astdrive := GetLastDrive;
    if lastdrive = 0 then
        Halt(0);

    Write o 'LASTDRIVE ', Chr(Ord('A'  - ) + lastdrive)),
    Halt(lastdrive);
end.
```

LAN DRIVE LAN has not only its own data structures, but doesn't adjust itself to the DOS version (as the small LASTDRV2.PAS which simply uses a static offset). This is the same kind of problem we face when we want to use the C programming interface. One solution is to use the object-oriented features added to Turbo Pascal 5.5 and 6.0. See Section 5.5, "Object-Oriented Programming," in *Mastering Turbo Pascal 6.0* (Indianapolis: Hayden Books, 1991) for a detailed discussion of writing a TP version sensitive objects that map DOS internal data structures.

Windows Turbo Pascal for Windows (TPW) offers a function, SysVersion, under Turbo Pascal for Windows. Not surprisingly, undocumented DOS calls are heavily employed. The unit source contains an undocumented call to retrieve the LASTDRIVE value. Other DOS calls give access to DOS device data structures from protected mode Windows programs that possess an LDT. For a discussion tailored to TPW, see the chapter on Access to Real Mode or DOS Services in *Master the Turbo Pascal for Windows Techniques and Utilities*.

Undocumented DOS Calls from BASIC

In the last two sections, the LASTDRV2 program checked the version of DOS and called undocumented DOS calls only if it found a DOS version greater than 2.x. Here is a BASIC program that uses undocumented DOS calls regardless of the DOS version. Microsoft BASIC 7.1 (the second BASIC version of LAN DRIVE) introduced 2.x-specific undocumented SysVars, so the program requires a DOSVERSION function that returns the major version number. Because the offset of LASTDRIVE within the SysVars

Listing 2-15 LASTDRV2.BAS

```
REM LASTDRV2.BAS
REM $INCLUDE: 'QB.BI'
DEF FNHI (x) = x \ &H100
DEF FNLO (x) = x AND &HFF

FUNCTION DOSVERSION
    DIM Regs AS RegType
    Regs.ax = &H3000            'should call &H3306 too'
```

```
    CALL INTERRUPT(&H21, Regs, Regs)
    DOSVERSION = Regs.ax
END FUNCTION

SUB DOSEXIT(errorlevel)
    CLOSE
    DIM Regs AS RegType
    Regs.ax = &H4C00 + errorlevel
    CALL INTERRUPT(&H21, Regs, Regs)
END SUB

REM based on DOS version number, find offset of LASTDRIVE
 lastdrvofs = &H21
vers = DOSVERSION
IF FNLO(vers) << 3 THEN DOSEXIT(0)
IF (FNLO(vers) = 3) AND (FNHI(vers) = 0) THEN lastdrvofs = &H1B

REM get address of SysVars
DIM Regs AS RegTypeX
Regs.ax = &H5200
Regs.es = 0
Regs.bx = 0

REM to use current value of DS, set to -1
Regs.ds = -1
CALL INTERRUPTX(&H21, Regs, Regs)
IF (Regs.es = 0) AND (Regs.bx = 0) THEN DOSEXIT(0)

REM peek at LASTDRIVE field within SysVars
DEF SEG = Regs.es
lastdrv = PEEK(Regs.bx + lastdrvofs)
IF lastdrv = &HFF THEN DOSEXIT(0)

REM print LASTDRIVE letter, return LASTDRIVE number
PRINT "LASTDRIVE= ", CHR$(ASC("A") - 1 + lastdrv)
CALL DOSEXIT(lastdrv)
END
```

Once INT 21h function 52h returns the address of SysVars in the ES:BX register pair, LASTDRV2.BAS uses DEF SEG and PEEK to read the LASTDRIVE byte. Check the section on "DOS Calls from BASIC" to see how to compile this code into a stand-alone executable. As noted there, the version of QBASIC included with MS-DOS unfortunately does not support CALL INTERRUPT.

When Not To Use Undocumented Features

The last few sections described in great detail the depths of DOS simply to bring back a piece of information that was readily available if you knew how to use DOS's well-documented function interface. This could be compared to an American who learns Japanese and then uses it to newly reopened ski resorts to watch American movies dubbed into Japanese.

This provides a worthy example of when *not* to use undocumented DOS. If there is a way to perform an operation using well-documented DOS program-to-DOS interface, use it. *Get out of the habit* to use the documented interfaces. If there is a seemingly convenient way to accomplish some task using the undocumented calls described in this book, and a less convenient way involving documented calls, use the documented calls. You'll see a good example of this in Chapter 7 where we discuss a brief temptation to use INT 29h.

The "Must Have Speed" approach to programming, the desire to use a function simply because it is there, is fine when you are experimenting with a new operating system, but it has no place in commercial software. One of our worries in producing this book was that it might encourage the over use of undocumented DOS. Please don't use undocumented DOS when documented DOS will do. Using undocumented calls and data structures ties your program to a particular implementation of the operating system, making it harder for the operating system to change and making compat-

...r DOS more difficult. The more programs depend on undocumented DOS, the more the whole industry will have to suffer under the backward compatibility stranglehold of MS-DOS.

Having said all this, though, let's remember that lots of successful commercial software for the PC uses undocumented DOS features. Certain things can't be done using only the documented interfaces; this is analogous to the situation with direct hardware access. Clearly, you should use direct hardware access only as a last resort, yet almost all successful PC software does some direct hardware access. Virtually, DOS programming takes place in this area of "last resort."

Verifying Undocumented DOS

Actually, there's one good reason for using undocumented DOS even when there is equivalent documented functionality. It would be nice to have a way to perform a baseline validation of the usability of an undocumented DOS feature given a version of DOS. Obviously, the best way to validate a value computed using undocumented DOS is to compare it to a known value with which it should be equivalent.

Because we can't hope to check the results of undocumented DOS against documented DOS because, if we could, we would be using documented DOS in the first place! To check that dosset lastdrive really is setting the lastdrive, getdisk or setdisk(0x11) for example, seems pointless. But what if we were able to check against a value that LASTDRIVE from the SysVars? Then successfully comparing dosset lastdrive against a known value might give your program enough confidence to proceed using undocumented DOS, whereas a mismatch would indicate that something was very wrong.

As a result, you might want your programs to incorporate something similar to the following function, undoc_dos_okay. (Listing 2-16)

Listing 2-16: undoc_dos_okay()

```
BOOL undoc_dos_okay(void)
{
    unsigned char far *sysvars;
    unsigned lastdrv_doc;

    /* could do 21/3306, but if DOS version number from 21/30 doesn't
       accurately reflect genuine DOS version number, then test should
       fail, and undoc_dos_okay() should return FALSE */

    /* get offset for LASTDRIVE within DOS List of Lists */
    unsigned lastdrv_ofs = 0x21;
    if (_osmajor >= 4) lastdrv_ofs = 0x21;
    else if ((_osmajor ==3) && (_osminor==0)) lastdrv_ofs = 0x1b;

    /* Get DOS Lists of Lists */
     _asm mov ah, 52h
     _asm int 21h
    _asm mov bx, bx
    _asm mov es, bx
     _asm int 21h
    _asm mov word ptr sysvars, bx
    _asm mov word ptr sysvars+2, es
    if (! sysvars) return FALSE;

    /* use documented DOS to verify results */
#ifdef __TURBOC__
    lastdrv_doc = setdisk(0xFF);    /* don't need getdisk() */
#else
     dos_setdrive(0xFF, &lastdrv_doc);
#endif
    return (sysvars[lastdrv_ofs] == lastdrv_doc);
}
```

If undoc_dos_okay returns TRUE, as with DOS 5.0, it's no guarantee that all code that employs undocumented DOS will work. However, if undoc_dos_okay returns FALSE, there's a good chance that something is wrong with the underlying operating system, and that your code will have to work

around this. For example, a ridiculous but okay fix to the QDOS 2.11 DOS.sys bytes would be vastly improved multiple DOS boxes of QDOS 2.20.

An interesting question is exactly what to test for. The test in Listing 2.16 is probably enough to reveal a true undocumented okay. I would need to test for more than the existence and location of LASTDRIVE. But once we make a DOS test that's so stringent and arbitrary that only MS-DOS could hope to pass. A good example is the VARDD code we examined in Chapter 1. That code is essentially Microsoft's version of a ridiculous okay. Another example is Microsoft's SetUNP.0 test discussed in Chapter 4.

Making Modifications

We noted earlier that Quarterdeck's LASTDRIV.COM cleverly uses the undocumented rather than the documented technique for retrieving the value of LASTDRIVE. One reason for this seemingly outrageous flouting of the normal rules of good behavior is that LASTDRIV.COM can also be used to *change* the value of LASTDRIVE. This is a good example of something that requires undocumented DOS.

To change the value of LASTDRIVE is, of course, a simple matter. You've seen where this value is stored in DOS's data segment; changing the value would involve nothing more than writing rather than reading this memory location.

But to *usefully* change LASTDRIVE requires a little more work. It normally involves adding or subtracting entries from DOS's internal drive table. For each logical drive DOS maintains a Current Directory Structure. As explained in more detail in Chapter 8, see the INT 21h/AH=52h sample program, the CDS marks the current working directory for each drive in the system. DOS also stores a number of these CDS structures. Its pointer to this array of CDS vars just like LASTDRIVE.

LASTDRIVE in fact is nothing more than the size of the CDS array. Quarterdeck's LASTDRIV.COM not only changes the value of LASTDRIVE, but also relocates and resizes the CDS array, locked into the purpose of LASTDRIV.COM is to relocate the CDS high out of low memory, below 1 megabyte, so that you can put LASTDRIVE=Z in CONFIG.SYS and also run LOADHI LASTDRIV.COM. Most other vendors' QEMM comes with similar utilities, such as Intel's INSTALL.COM or Qualitas' 386MAX.COM, for relocating other DOS internal data structures, such as those returned from INT 21h function 52h.

How does all this work? Once again, we'll disassemble QEMM's LASTDRIV.COM. Like most of the programs we've examined, LASTDRIV.COM is a mixture of machine instructions and data. Disassembly produces understandable results only in the machine code areas. Data areas produce meaningless instructions and error messages. However, it is a necessary step in discovering how LASTDRIV.COM works. Before the program INSTRSPY contains code that handles LASTDRIV calls (INT 21h function 52h). A few moments thought about the problem of relocating the CDS reveals a likely pseudocode, shown in Listing 2.17.

Listing 2.17: Pseudocode for Changing LASTDRIVE

```
get new_lastdrv from command line,
get sysvars from INT 21h AH=52h
set LASTDRV_OFS and CDS_PTR_OFS based on DOS version,
old_lastdrv = sysvars[LASTDRV_OFS],
old_cds   = sysvars[CDS_PTR_OFS],
sizeof_cds_entry depends on DOS version,
new_cds = allocate(new_lastdrv * sizeof_cds_entry),  // LOADHI
disable interrupts,
memcpy(new_cds, old_cds, old_lastdrv * sizeof_cds_entry),
mark newly formed CDS entries as invalid drives,
sysvars[LASTDRV_OFS]  = new_lastdrv,
sysvars[CDS_PTR_OFS] = new_cds;          // do it!
enable interrupts,
```

```
// hope that no one has a dangling invalid pointer to old_cds!
 / (in any case, can't free it because don't know how it was allocated)
```

Basically, reallocating the CDS is a matter of allocating a block of memory for the new CDS, copying the old CDS into it, and updating the CDS pointer and LASTDRIVE value in SysVars. It is easy to turn these steps into a working program. Listing 2-18 shows XLASTDRV.C, which for the most part just carries out the actions shown in the pseudocode.

Listing 2-18. XLASTDRV.C

```
/*
XLASTDRV.C
Andrew Schulman, May 1993

bcc xlastdrv.c ..\chap3\iswin.c

Straightforward clone of QEMM LASTDRIV.COM utility, except
   Checks for presence of Windows Enh mode (DOSMGR hangs onto original
   CDS pointer from SysVars), refuses to run in DOS box
 - Checks for presence of Windows Std mode and task switcher (suggested
   by Ralf Brown).  Otherwise, DOS box can be closed, thereby deallocating
   XLASTDRV's CDS!
   Checks for presence of DesqView (suggested by Ralf Brown): the new
   CDS would be in remapped memory that isn't guaranteed to be around when
   a DOS call uses the CDS.
   Uses sleazy hack to try to free up previously-created XLASTDRV CDSes
   Uses  'instant TSR' technique from Prosise UNDELES
-- Provides  RESTORE command to put back original CDS pointer and LASTDRIVE
   from SysVars, uses sleazy hack entry to save these away.  This necessary
   for MSCDEX and other utilities and hold onto original SysVars pointers.
Ok, not such a straightforward clone after all!
*/

#include <stdlib.h>
#include <stdio.h>
#include <ctype.h>
#include <string.h>
#include <dos.h>
#ifdef __TURBOC__
#include <alloc.h>
#include <dir.h>
#else
#include <direct.h>
#endif

typedef unsigned char BYTE;
typedef unsigned short WORD;
typedef unsigned long DWORD;

# ifndef min
#define min(a,b)    (((a) < (b)) ? (a) : (b))
#endif

#ifndef MK_FP
#define MK_FP(seg,ofs) \
    ((void far *)(((DWORD)(seg) << 16) | (ofs)))
#endif

typedef struct {
    BYTE zero, far *orig_cds, orig_lastdrv, signature[];
    } SLEAZY_HACK;

#define GET_SLEAZY_HACK(cds, ld)    \
     (SLEAZY_HACK far *) ((cds)+(((ld)-1)*sizeof_cds_entry))

#define XLASTDRV_SIGN       "XLASTDRV sleazy hack"

// \undoc2\chap3\iswin.c
extern int is_win(int *pma), int *pmin, int *pmode);
```

```
extern int detect_switcher(void);
void set_genuine_dos_vers(void);
BYTE far *get_sysvars(void);
void set_mcb_owner(WORD para, WORD owner);
void set_mcb_name(WORD para, char far *name);
int get_lastdrive_doc(void);
unsigned desqview(void);
void fail(char *s) { puts(s); exit(1); }

main(int argc, char *argv[])
{
    SLEAZY_HACK far *old_hack, far *new_hack;
    BYTE far *sysvars, far *old_cds, far *new_cds;
    unsigned int para;
    int lastdrv_ofs, cdsptr_ofs, new_lastdrv, old_lastdrv;
    int sizeof_cds_entry;
    int do_restore = 0;
    int dummy;

    if (argc < 2)
        fail("XLASTDRV [new value for lastdrv: A-Z] or -restore");

    if (is_win(&dummy, &dummy, &dummy))  // including Std mode (see Listing 3-29)
        fail("Sorry, XLASTDRV can't run under Windows");
    if (detect_switcher() != 0) // other than Std mode (see Listing 3-29)
        fail("Sorry, XLASTDRV can't run under a task switcher");
    if (desqview() != 0)
        fail("Sorry, XLASTDRV can't run under Desqview");

    // get new LASTDRV (or -RESTORE) from command line
    if (strcmp(strupr(argv[1]), "-RESTORE") == 0)
        do_restore = 1;
    else
        new_lastdrv = 1 + (toupper(argv[1][0]) - 'A');

    // possibly change _osmajor, _osminor, see if ok
    set_genuine_dos_vers();
    if ((_osmajor < 3) || (_osmajor >= 10))
        fail("Unsupported DOS version");

    // get offsets within SysVars
    if ((_osmajor == 3) && (_osminor == 0))
    {
        cdsptr_ofs = 0x17;
        lastdrv_ofs = 0x1b;
    }
    else
    {
        cdsptr_ofs = 0x16;
        lastdrv_ofs = 0x21;
    }

    // old_lastdrv = sysvars[lastdrv_ofs];
    if (!(sysvars = get_sysvars()))
        fail("Can't get SysVars");
    old_lastdrv = sysvars[lastdrv_ofs];

    // see if SysVars looks ok
    // get_lastdrive_doc() is wrong for Novell   see Listing 2-19
    if (get_lastdrive_doc() != old_lastdrv)
        fail("Internal DOS data structures wrong?");
    if (old_lastdrv == 0xff)
        fail("LASTDRIVE not supported");

    // old_cds = sysvars[cdsptr_ofs];
    old_cds = *((BYTE far * far *) &sysvars[cdsptr_ofs]);
```

```
// sizeof_cds_entry depends on DOS version;
if (_osmajor == 3)
    sizeof_cds_entry = 0x51;
else
    sizeof_cds_entry = 0x58;

if (do_restore)
{
    old_hack = GET_SLEAZY_HACK(old_cds, old_lastdrv);
    if (_fstrcmp(old_hack->signature, XLASTDRV_SIGN) != 0)
        fail("Can't restore original CDS!");
    _disable();
    _fmemcpy(old_hack->orig_cds, old_cds,
        min(old_lastdrv, old_hack->orig_lastdrv) * sizeof_cds_entry);
    *((BYTE far * far *) &sysvars[cdsptr_ofs]) = old_hack->orig_cds;
    sysvars[lastdrv_ofs] = old_hack->orig_lastdrv;
    _enable();
    printf("Restored CDS to %Fp (LASTDRIVE=%c)\n",
        old_hack->orig_cds,
        (old_hack->orig_lastdrv - 1) + 'A');
    goto free_old;
}

if (new_lastdrv != old_lastdrv)
    printf("Changing LASTDRIVE from %c to %c\n",
        (old_lastdrv - 1) + 'A',
        (new_lastdrv - 1) + 'A');

// temporarily bump up new_lastdrv for signature entry
new_lastdrv++;

// new_cds = allocate(new_lastdrv * sizeof_cds_entry);
if (_dos_allocmem((new_lastdrv * sizeof_cds_entry) >> 4,
    &para) != 0)
    fail("Insufficient memory");
new_cds = (BYTE far *) MK_FP(para, 0);

// This taken from Jeff Prosise, UNDFILES.EXE, 11/26/91
// Instant TSR!  (MEM /D thinks XLASTDRV is TSR)
set_mcb_owner(para, para);
set_mcb_name(para, "XLASTDRV");

// mark newly-formed CDS entries as invalid drives
_fmemset(new_cds, 0, new_lastdrv * sizeof_cds_entry);
printf("Moving CDS from %Fp to %Fp\n", old_cds, new_cds);
_disable();  // disable interrupts while moving CDS
// copy old CDS entries over to new CDS table
_fmemcpy(new_cds, old_cds,
    sizeof_cds_entry * min(new_lastdrv, old_lastdrv));
// put back actual new LASTDRIVE value requested by user
new_lastdrv--;
// use extra entry for signature, and to keep orig to restore
new_hack = GET_SLEAZY_HACK(new_cds, new_lastdrv);
old_hack = GET_SLEAZY_HACK(old_cds, old_lastdrv);
 _fstrcpy(new_hack->signature, XLASTDRV_SIGN);
if (_fstrcmp(old_hack->signature, XLASTDRV_SIGN) == 0)
{
    // have done XLASTDRV before, copy orig values from old to new
    new_hack->orig_cds = old_hack->orig_cds;
    new_hack->orig_lastdrv = old_hack->orig_lastdrv;
}
else
{
    // this is first time we've run XLASTDRV
```

```
        new_hack->orig_cds = old_cds;
        new_hack->orig_lastdrv = old_lastdrv;
    }
    // plug new values into SysVars'
    *((BYTE far * far *) &sysvars[cdsptr_ofs]) = new_cds;
    sysvars[lastdrv_ofs] = new_lastdrv;

    _enable();   // new CDS in place, re-enable interrupts

    // hope that no one has a dangling invalid pointer to old_cds'
    // Windows does, MSCDEX does'

free_old:
    // if we allocated old one, we can free it
    if (_fstrcmp(old_hack->signature, XLASTDRV_SIGN) == 0)
    {
        if (_dos_freemem(FP_SEG(old_cds)) != 0)
            fail( Couldn't free up old CDS");
        else
            printf( freed old XLASTDRV CDS at %Fp\n", old_cds);
    }
    return 0;
}
void set_genuine_dos_vers(void)
{
    union REGS r;
    r.x.ax = 0x3306;
    r.x.bx = 0;
    intdos(&r, &r);
    if (r.x.bx != 0)
    {
        _osmajor = r.h.bl;
        _osminor = r.h.bh;
    }
}
BYTE far *get_sysvars(void)
{
    union REGS r;
    struct SREGS s;
    r.h.ah = 0x52;
    segread(&s);
    s.es = r.x.bx = 0;
    intdosx(&r, &r, &s);
    return (BYTE far *) MK_FP(s.es, r.x.bx);
}
void set_mcb_owner(WORD para, WORD owner)
{
    *((WORD far *) MK_FP(para-1, 1)) = owner;
}
void set_mcb_name(WORD para, char far *name)
{
    _fmemcpy(MK_FP(para-1, 8), name, 8);
}
unsigned desqview(void)
{
    _asm mov ax, 2801h
    _asm mov cx, 4445h  /* 'DE' */
    _asm mov dx, 5351h  /* 'SQ' */
    _asm int 21h
    _asm cmp al, 0FFh
    _asm je no_desq
    _asm mov ax, bx     /* BH=major, BL=minor */
    _asm jmp short done
```

```
no_desq
    _asm xor ax, ax     /* return 0 */
done:
    // return value in AX
}

int get_ lastdrive_doc(void) // should adjust for Novell!
{
#ifdef __TURBOC__
    return setdisk(0xff);
#else
    unsigned lastdrv_doc;
    _dos_setdrive(0xFF, &lastdrv_doc);
    return lastdrv_doc;
#endif
```

After XLASTDRV or any DOS uses the new CDS it allocates just as if it were DOS's own creation. Switching the two CDS values confuses SysVars look-alike. However, if you run MEM /D or the /DYNAMIC option from Chapter 7, you will see that these utilities don't know that the CDS has moved. And it seems impossible to tell them about it. The QEMM LASTDRIVE utility has the same problem. But aside from these problems, DOS accepts the new CDS as its own.

To relocate the CDS high, just run LH XLASTDRV or LOADHIGH XLASTDRV. XLASTDRV will continue to allocate memory for the new CDS using the Microsoft and Borland DOS memory services which calls INT 21h function 48h. If you run XLASTDRV under LOADHIGH, DOS will have just allocated the memory from a UMB. While it would be easy enough to make XLASTDRV UMB-aware (see /X), Microsoft's UMBPEEK.SYS driver, for example, this step really isn't necessary. For an explanation of how LOADHIGH works, see Chapter 7.

Most XLASTDRV *don'ts* have to worry about is making sure that the memory for the new CDS was allocated from the proper area. When XLASTDRV exits, DOS walks the Memory Control Block chain and frees up the space occupied by XLASTDRV. It seems like overkill to make the program a TSR so it can spend time allocating a block of memory for the new CDS. XLASTDRV changes the block's owner so that DOS doesn't free the block when XLASTDRV exits. In essence, this procedure creates a private TSR. (See Chapter 7 for details of the MCB chain.)

It is a simple matter to free up the old CDS. We can't free the original CDS owned by DOS, even though it is no longer in use, because we don't know how it was allocated. But we can free up any earlier CDSs that XLASTDRV itself created. Remember its own CDS allocations. XLASTDRV allocates an extra CDS every time it runs. When XLASTDRV starts back 7 it finds every CDS but the last one it made. CDS 1 knows how to delete the old CDS.

Listing 8-10 provides a few of the utilities we'll use to explore techniques of relocating internal DOS data structures to UMBs. Relocation depends on a completely undocumented convention that the operating system never creates or uses TSRs always go to the high SysVars. If a resident program gets a pointer to the CDS from the SysVars once during initialization and uses it thereafter without referring back to SysVars, the system has split in two. Only if XLASTDRV or any similar program comes along later and changes the CDS pointer in SysVars.

For example, the Microsoft CD-ROM Extensions MSCDEX save away a pointer to the CDS. If XLASTDRV changes the CDS location, MSCDEX can no longer find its CD-ROM drives. XLASTDRV provides a /RESTORE switch which puts the CDS back to its original location. Of course, an isolated TSR doesn't work, but at least MSCDEX works again.

Note in Listing 2-18 that XLASTDRV uses ISWIN() (from Chapter 3 / Listing 3-29) to see if Windows is present. Windows Enhanced mode does not allow this always refer to SysVars convention at all. The DOSMGR.VxD only checks SysVars once, during its initialization, and isn't prepared for the SysVars CDS pointers to change after this. As seen back in Listing 1-10, DOSMGR hangs on to these as linear addresses and isn't prepared for LASTDRIVE to change. Thus, while running

FILES or LASTDRIVE before Windows works fine running either of these programs from a DOS box. But exit mode DOS box is a recipe for disaster. And because the code in DOSMGR that does the INT 21h AH=52h to check SysVars is discarded from memory after initialization, there probably isn't enough room in that favorite memory patching DOSMGR needs to do the right thing. These pointers in SysVars aren't change once Enhanced mode starts running. This means that all virtual machines have identical copies of these SysVars pointers. We'll actually take advantage of this fact in the next chapter in a Windows program ENUMDRV.C that displays the CDS structures in DOS box (see Listing 3-2).

This problem isn't just a Windows problem. In fact, in the first edition of this book I provided the "helpful" advice that programs using INRs should seek the List of Lists structure during initialization and thereafter hang onto and use pointers in the CDS SFT and so on. This advice is okay as long as assuming that these pointers don't change, but some clever programmers have written programs that take these pointers and change! Hopefully, my comments also followed my advice in the first edition, but unfortunately Windows and MSCDEX have long followed the same logic.

XLASTDRV.C also checks for the presence of Windows Standard mode. For a task switcher such as the DOS shell and for DesqView, task switchers such as Standard mode and the DOS shell are not good places to run XLASTDRV. A session of DOS box could be closed down by forcefully terminating XLASTDRV.C. Under DesqView, XLASTDRV's view of CDS would be in remapped memory that isn't guaranteed to be accessible when a DOS application accesses the CDS. Basically, there are a lot of restrictions on moving DOS internal structures.

An Important Special Case: Novell NetWare

There's an added complexity to using undocumented DOS for getting LASTDRIVE. In one situation, the documented method is actually less reliable than the undocumented method. On a lot of the many PCs that are Novell NetWare workstations, INT 21h function 0Eh doesn't return the value of LASTDRIVE. It returns the number 32, corresponding to the number of possible network drive mappings (drive letters A through Z, plus ten special drive letters with the sub-names of 0, 1, 2, ... 9). Thus, under NetWare, the versions of LASTDRIVE that use undocumented DOS display correct values for LASTDRIVE, whereas the supposed "safer" documented version of LASTDRIVE that uses only documented DOS always prints out the following display:

```
C:\UNDOC2\CHAP2>lastdrv
LASTDRIVE=Z
```

Likewise, under NetWare, the return value of the "get current drive" function returns FALSE. This happens not because undocumented DOS is broken, but because documented function 0Eh is returning a strange value.

It is important to discuss these issues since Novell is easily the largest supplier of PC local area network (LAN) software. Its share of the PC LAN software market is probably more than that of its nearest competitor, Microsoft, by a wide margin. Novell's dedication to PC operating systems has made few inroads into Novell's dominance over the PC network market. In the context of LASTDRV, that uses documented DOS doesn't work under Novell NetWare, because it doesn't work.

How does the NetWare shell customize a workstation's DOS so that INT 21h function 0Eh returns 32 instead of the number of LASTDRIVE? Easy. The shell hooks DOS and emulates the return value from function 0Eh. You'll see exactly what "hooking DOS" means in a few moments. Chapter 4 also discusses the workings of the Novell workstation shell NETX in enough detail.

Novell's undocumented function 0Eh is unfortunately not NetWare's only alternate function. INT 21h function 0Dh, which returns the correct value of LASTDRIVE, also is not part of undocumented DOS and doesn't appear in the appendix. However, INTRLIST.ZIP's companion disk describes this function. To be compatible with NetWare, we need to change our initial checks to

Instead of asserting that undocumented DOS is unusable simply because doslist >lastdrive != setdisk (0xFF) — the improved version of undoc_dos_okay() performs a slightly more complicated test, as shown in Listing 2-19:

Listing 2-19: OKAY.C

```
/*
OKAY.C -- basic test for validity of undocumented DOS
cl -DTESTING okay.c
*/

#include <stdlib.h>
#include <stdio.h>

#ifdef __TURBOC__
#include <dir.h>
#endif

typedef int BOOL;
#define FALSE   0
#define TRUE    (! FALSE)

BOOL netware(void);
unsigned lastdrv_netware(void);

BOOL undoc_dos_okay(void)
{
    unsigned char far *sysvars;
    unsigned lastdrv_doc;

    /* could do 21/3306, but if DOS version number from 21/30 doesn't
       accurately reflect genuine DOS version number, then test should
       fail, and undoc_dos_okay() should return FALSE */

    /* get offset for LASTDRIVE within DOS List of Lists */
    unsigned lastdrv_ofs = 0x21;
    if (_osmajor==2) lastdrv_ofs = 0x10;
    else if ((_osmajor>=3) && (_osmajor<=0)) lastdrv_ofs = 0x1b;

    /* Get DOS Lists of Lists */
     _asm mov ah, 52h
    _asm xor bx, bx
    _asm mov es, bx
    _asm int 21h
    _asm mov word ptr sysvars, bx
    _asm mov word ptr sysvars+2, es
    if (! sysvars) return FALSE;

    /* use documented DOS to verify results */
#ifdef __TURBOC__
    lastdrv_doc = setdisk(0xFF);
#else
    _dos_setdrive(0xFF, &lastdrv_doc);
#endif
    if (sysvars[lastdrv_ofs] == lastdrv_doc)
        return TRUE;
    else if (netware())
    {
        puts("Novell NetWare");
        if (lastdrv_doc != 32)
            puts("NetWare INT 21h 0Eh looks strange");
        return (sysvars[lastdrv_ofs] >= lastdrv_netware());
    }

    return FALSE;
}

/*  Novell Return Shell Version function (INT 21h AH=EAh AL=01h)
    see INTERLIST on accompanying disk; also see Barry Nance,
    _Networking Programming in C_, pp. 317, 341-2. */
```

```
BOOL netware(void)
{
    char buf[40];
    char far *fp = buf;
    _asm push di
    _asm mov ax, 0EA01h
    _asm mov bx, 0
    _asm les di, fp
    _asm int 21h
    _asm xor al, al
    _asm mov ax, bx
    /* if BX still 0, then NetWare not present, return in AX */
    _asm pop di
}
/*  Novell Get Number of Local Drives function (INT 21h AH=D8h).
    See INTRLIST on accompanying disk, or Charles Rose, _Programmer's
    Guide to NetWare_, p. 731. */
unsigned lastdrv_netware(void)
{
    _asm mov ah, 0D8h
    _asm int 21h
    /* AL now holds number of "local drives" (genuine LASTDRIVE) */
    _asm xor ah, ah
    /* unsigned returned in AX */
}
#ifdef TESTING
main()
{
    fputs("Undocumented DOS ", stdout);
    puts( undoc_dos_okay() ? "ok" : "not ok");
}
#endif
```

Function 0EH isn't the only DOS function whose behavior Novell NetWare modifies. The NetWare shell inspects every INT 21h function request before DOS itself sees it. The shell decides whether to pass that int 21h request along to DOS or to pass the request over the network to another machine, the server, which runs a copy of DOS. Finally, even if the shell decides to pass the INT 21h function request along to DOS, it gets to modify any registers before it turns control to the application, such as LASTDRV, that called INT 21h in the first place. For further details on DOS differences under NetWare, see Chapter 4.

Hooking DOS: Application Wrappers

Seeing that NetWare changes DOS function 0E1h gives us an excuse to look into what it means for a program to "hook DOS." In order to hook DOS, all a program has to do is get the address of the current interrupt handler for INT 21h and then install its own handler for INT 21h. There's nothing difficult or undocumented about this capability. It's built right into DOS itself and is one of the key facilities that makes DOS extensible.

We can simulate NetWare's handling of function 0E1h and provide a realistic example of hooking DOS by using just a few lines of code. Generally, programs that hook DOS, like Novell's workstation shells, are memory resident. However, there is no reason such programs must be TSRs. As FUNC0E32.ASM in Listing 2-20 shows, it's easier to build a program that instead acts as a shell or wrapper around another program (see Jim Kyle, "Application Wrappers," *PC Techniques*, June/July 1992). FUNC0E32 modifies function 0EH to return 32, just like NetWare, and then uses one of the EXEC spawn functions to run whatever program was specified on its command line. For example,

```
C:\UNDOC2\CHAP2>func0e32 lastdrv.exe
LASTDRIVE='
10 DOS calls
1 changed
```

Any version of LASTDRV that uses only documented DOS functions is fooled by FUNC 0E32, but the versions that use undocumented DOS aren't. For example

```
C:\UNDOC2\CHAP2>func0e32 lastdrv2.exe
LASTDRIVE=E
10 DOS calls
1 changed
```

FUNC0E32.C (in Listing 2-20) consists of two functions. The function DOS() is our INT 21h handler. We want DOS() to get control each time anyone invokes INT 21h. DOS() changes the value that Function 0Eh returns in AL to 32; the function also keeps count of how many INT 21h calls it has seen and how many it has changed. It is FUNC0E32 which produces the "10 DOS calls" and "1 changed" output above. In Listing 2-20, main() installs DOS() as the INT 21h handler, spawns the program name for the command line, and then restores the original INT 21h handler, which may be DOS itself but which on most PCs will be some other program that had earlier hooked DOS, such as NetWare.

Listing 2-20: FUNC0E32.C

```
/* FUNC0E32.C -- take over INT 21h Function 0Eh; return 32 in AL */

#include <stdlib.h>
#include <stdio.h>
#include <process.h>
#include <dos.h>

#pragma pack(1)

typedef struct {
#ifdef __TURBOC__
    unsigned short bp,di,si,ds,es,dx,cx,bx,ax;
#else
    unsigned short es,ds,di,si,bp,sp,bx,dx,cx,ax;  /* same as PUSHA */
#endif
    unsigned short ip,cs,flags;
    } REG_PARAMS;

void _interrupt _far DOS(REG_PARAMS r);
void (_interrupt _far *old)(void);
unsigned long calls = 0;
unsigned long changed = 0;

void fail(char *s) { puts(s); exit(1); }

main(int argc, char *argv[])
{
    if (argc < 2)
        fail("usage: func0e32 [program name] <args ..>");

    old = (void (interrupt far *)(void)) _dos_getvect(0x21);
    _dos_setvect(0x21, DOS);            /* hook INT 21h */
    if (spawnvp(P_WAIT, argv[1], &argv[1]) == -1) /* run command */
        puts("Can't run program");
    _dos_setvect(0x21, old);            /* unhook INT 21h */

    printf("\n%lu DOS calls\n", calls);
    printf("%lu changed\n", changed);
    return 0;
}

void _interrupt _far DOS(REG_PARAMS r)
{
```

```
    _asm pusha
    calls++;
    if ((r.ax >> 8) == 0x0E)  /* if Function 0Eh, . */
    {
        _asm popa
        (*old)(),             /* first call old INT 21h handler */
        r.ax = 0x0E20,        /* then force #drives to 20h (32) */
        changed++,
    }
    else                      /* not for us */
    {
        _asm popa
        _chain_intr(old),     /* pass to old INT 21h handler */
    }
}
```

This code is important not only to illustrate that it is perfectly legitimate (and completely documented) for a company like Novell to change the return value from a DOS function, but it is also an example of how to hook a DOS interrupt like INT 21h. Some undocumented DOS functions are not for you to call, but for you to *implement* so that DOS can call them down the road to call you. Such functions are indicated in the appendix with the phrase "Called with" For example, the DOS network redirector, which under MS-Net and several other networks, is one standard set of call back functions. A network redirector program takes over INT 2Fh and looks for calls to AH=11h with subfunctions in AL.

Listing 2.20 shows you how to hook an interrupt with just a few lines of code. The DOS.H header files provided by Microsoft, Borland, and other PC compiler vendors declares the functions dos_setvect and dos_getvect. The _interrupt keyword defines a C function as a target for a hook. The compiler pushes all the CPU registers on the C interrupt function's stack; see REG_PARAMS in Listing 2.20. Unfortunately, Microsoft and Borland do register access differently. Microsoft C 6.0 and earlier can't access the registers using expressions such as _AX = 0x0E20; either way, the interrupt handler can access the registers using expressions such as r.ax = 0x0E20;

Of course, the new interrupt handler generally needs to call down to the previous handler. Eventually, the new handler needs to get control again after calling the previous handler. The new handler is typically terminated with an expression such as "chain_intr(old);" The new handler doesn't need to know where "old" is located. "old" wants to "chain" to the previous handler. You can use the function chain_intr provided in both Microsoft C 6.0 and as a recent addition to Borland C++. If your compiler doesn't have a documented chain_intr, check your compiler's run-time library source code (for example, borlandc\src\lib\chainintr.asm).

FUNC0E32 is a rather specialized and contrived example of how a DOS interrupt handler can wrap another. As another example of hooking DOS, let's consider the DOSVER program shown in Listing 2.21. This program takes over INT 21h, changes the DOS version number that applications ask for, and then terminates but remains resident in memory. The effect is permanent in its effect.

Listing 2.21: DOSVER.C

```
/* DOSVER.C -- set different DOS version numbers */

#include <stdlib.h>
#include <stdio.h>
#include <process.h>
#include <dos.h>

#pragma pack(1)

void (interrupt far *old)();
unsigned dosver, old_bx, old_cx;

typedef struct {
```

```
#ifdef __TURBOC__
    unsigned short bp,di,si,ds,es,dx,cx,bx,ax;
#else
    unsigned short es,ds,di,si,bp,sp,bx,dx,cx,ax,   /* PUSHA order */
#endif
    unsigned short ip,cs,flags,
    } REG_PARAMS;

void interrupt far dos(REG_PARAMS r)
{
    if ((r.ax >> 8) == 0x30)
    {
        r.ax   dosver,
        r.bx = old_bx,
        r.cx = old_cx,
    }
    else
        _chain_intr(old),
}

void fail(char *s) { puts(s); exit(1); }

main(int argc, char *argv[])
{
    int new_major, new_minor;
    unsigned char old_major, old_minor,

    if (argc < 4)
        fail("usage: dosver <major> <minor> <command,, >\n"
             "example:  dosver 3 31 exe2bin devlod.exe devlod.com");

    if (! (new_major = atoi(argv[1])))
        fail("bad version number"),
    if ((new_minor = atoi(argv[2])) < 10)       /* e.g. 3.1 to 3.10 */
        new_minor *= 10;
    dosver   (new_minor << 8) + new_major;

    _asm mov ax, 3000h
     asm int 21h
    _asm mov old_major, al
    _asm mov old_minor, ah
    _asm mov old_cx, cx                         /* OEM, serial# */
    _asm mov old_bx, bx

    if ((new_major    old_major) && (new_minor >= old_minor))
        fail("no change");

    printf("Changing DOS version from %u.%02u to %u.%02u\n",
        old_major, old_minor, new_major, new_minor),

    old = _dos_getvect(0x21);                   /* save INT 21h */
    _dos_setvect(0x21, dos);                    /* hook INT 21h */
    if (spawnvp(P_WAIT, argv[3], &argv[3]) == -1) /* run command */
       puts("Can't run program"),
     dos_setvect(0x21, old),                    /* unhook INT 21h */
    return 0;
}
```

In addition to its occasional uselessness with programs that are over conservative in their response to the DOS version number, DOSVER and FUNC0E32 can also be lashed together to thoroughly mess up both INT 21h functions 30h and 0Eh and to see if the LASTDRV programs respond properly. For example, the following test run under DOS 6.0 perversely sets the DOS version number to 3.31 and then makes function 0Eh return 32, but LASTDRV 4 from Listing 2-10 recovers and gets the correct answer:

```
C:\UNDOC2\CHAP2>dosver 3 31 func0e32 lastdrv4
Changing DOS version from 6.00 to 3.31
```

```
21/30 returns 3.31
But 21/3306 returns 6.00
LASTDRIVE=M

45 DOS calls
0 changed
```

If you haven't written a C interrupt handler before, you may want to experiment with INT 08, 1C, or DOSVER.C, perhaps modifying them to count and display the number of different INT 21h calls. Try adding an additional INT 21h handler to count the number of INT 21h calls an application makes. This should take less than 100 lines of code, yet it would be a worthwhile scaled-down version of the INTRSPY program from Chapter 5.

On to Protected Mode

Frankly, it is a bit difficult to take seriously all the little character mode DOS programs we've developed in this chapter. In the 1990s most new development of the PC is being done for Windows, or even for computers different from DOS operating systems such as OS/2 and Windows NT. Little utilities that print LASTDRIVE=M almost seem like a joke. They have something of a retro-nerd "look what I can do with my computer" feel to them.

But vestiges of MS-DOS systems programming and undocumented DOS really haven't gone away. Far from it. Windows applications running in protected mode often need to talk to DOS TSRs and device drivers. In protected mode, developers often want some way for their Windows applications to get at something from a DOS box. OS/2 and NT emulate DOS and provide support so it's not known whether any of this undocumented DOS stuff works in these DOS emulations. Unless pointed DOS hasn't gone away. As we'll see in the next two chapters, it's just become a lot more complicated.

CHAPTER 3

Undocumented DOS Meets Windows

by Andrew Schulman

The previous chapter has shown how to call undocumented DOS functions and access undocumented DOS data structures from a wide assortment of programming languages. But in most cases the assumption was that the software was a real-mode DOS program. Microsoft designed the MS-DOS operating system to run on the late 8088 microprocessor and even on the hottest Pentium or 80486 processor with megabytes of memory, MS-DOS still runs in real mode, limiting programs to a single megabyte of linear address space (or worse).

Fortunately, almost no hardware today makes 8088-based PCs economical, and most developers write real-mode DOS programs for Windows specifically because memory- and DOS-only development is relatively straightforward. Many useful PC software products, such as those for Windows and other protected-mode DOS extenders, run in protected mode. In protected mode, DOS programs can directly access the whole address space of memory on the 80286 and higher processors. The great importance of Windows 3 is that it forces developers to access what Windows programs run in protected mode.

But even with the new Windows 3 protected mode, DOS calls are not quite as easy. Windows protected-mode applications generally cannot call DOS directly. Instead, they must use Windows services to accomplish DOS and BIOS functions. Under DOS, Windows programs run in protected mode on the 80286 and higher processors. Under DOS, Windows programs can access extended memory, the processor's address space above 1MB. DOS cannot. DOS is a real-mode operating system. Windows programs cannot call DOS directly. Instead, they must call DOS through Windows. For example, the Windows API function `DOS3Call` executes an `INT 21h` instruction. `DOS3Call` is called from the Windows API function `GetVersion`, which in turn calls `INT 21h` function, which in turn calls `INT 21h`.

When Windows 3 switches a program from DOS's real mode to protected mode, it must provide `INT 21h` (the primary DOS service) for Windows to intercept a protected-mode program's `INT 21h` calls to something that can reach DOS. Windows provides real-mode DOS's real-mode segment base address. It is not clear that this protected-mode segment can be established. For a more complete discussion of DOS extenders and protected mode, see the second edition of *Extending DOS*, edited by Ray Duncan.

Just as Windows programs must call DOS through Windows, they must also call undocumented DOS functions through Windows. But when Windows programs have attempted access to the standard documented DOS functions through `INT 21h`, they have run into problems. Most DOS functions generally *do not* work correctly. For example, when a protected-mode Windows program calls DOS to open a file with an `INT 21h` `AH=3Dh` without exactly the correct pointer to the file's name, which is usually located in extended memory, it is not enough for a Windows program to call an undocumented function such as `INT 21h` `AH=52h` and then access a data structure that DOS has

Standard and Enhanced mode DOS extenders built into Windows 3.0 and 3.1 do not support many undocumented DOS functions and data structures.

In addition to being a DOS extender that is a provider of protected mode INT 21h services, Windows also provides an implementation of version 0.9B of the DOS Protected Mode Interface (DPMI). DPMI includes services for generating real mode interrupts from protected mode, mapping real mode memory into protected mode programs address space, and so on. As this chapter details, a Windows program can use these services to access undocumented DOS because Windows programs run in protected mode and have explicit access to DPMI. DPMI details: Using DPMI to create the LASTDRV program from Chapter 2 for example, as a Windows program. Yet another version of LASTDRV.

Interestingly enough, even though DPMI is a Windows version of LASTDRV could instead use some undocumented Windows API functions to access the undocumented DOS data structures. Some of DPMI services access undocumented structures in the Windows. Windows itself uses a number of undocumented DPMI functions. There are vast numbers of undocumented Windows API calls. However, these topics will be addressed in separate book, *Undocumented Windows*, forthcoming from Addison-Wesley to complement undocumented aspects of Windows. What this chapter covers, however, is how to use existing Windows API that is sometimes overlooked undocumented DOS.

Chapter 1 showed that Windows itself makes heavy use of undocumented DOS and presented a wide variety of tools (DOSMGR.EXE, a device driver, VxD) that indicate how one would go about using undocumented DOS from a VxD. This is important because VxDs are the interface to DOS systems programming under Windows. While the VxD chapter focuses most on writing VxDs, Windows applications that use undocumented DOS could also benefit from the code. Windows Enhanced mode uses a lot of DOS extender and DPMI services. The end of this chapter will present a simple VxD that provides a transparent interface to a few selected DOS functions that Windows does not otherwise support.

Several articles and books that have appeared since the release of Windows 3.0 have already discussed how to use DPMI to access undocumented DOS functions and data structures. However, Enhanced mode Windows provides a substantial number of additional services for protected mode. Enhanced mode provides support services for both real mode programs in virtual 8086 mode, and protected mode. Each DOS box has its own private DOS, including separate instances of important DOS data structures such as the Current Directory Structure and Swappable Data Area.

Interrupt 2Fh, AX=1220h in Chapter 3 showed two DOS tables in Windows, one setting at [CS:DX] for compatibility mode and the Multiplex Manager setting at [WIN31]. In other words, Enhanced mode supports multiple DOS. Beyond the incompatibilities this chapter presents is the fundamental issue of how VxDs and services of DOS look from a Windows program or even from a DOS program running under Windows.

The problem is bridges between real mode and protected mode. This sounds "simple," but in practice it is the most complex software your program depends on will have already been ported to protected mode. Even so, today many programs depend on other components which have been ported to protected mode. For the foreseeable future, be able to get to real mode from protected mode should be a necessary and marketable skill. This is not especially true of Windows applications in general as a necessary real world engineering skill.

This chapter discusses the other topics including writing simple Windows programs without using Windows or Basic messages, using DPMI to write protected mode DOS programs, protected mode PSP and Segment Environment values under Windows, using INT 21h to call services provided by Windows, VxDs, writing Windows VxDs, and examining how Windows implements its DOS extender and DPMI server.

Before we begin, a brief appeal to those DOS programmers who "don't do Windows" please don't skip this chapter. We will be dragged into Windows down to the level of DOS systems programming. Even others, specifically even the most hard-nosed and ranting DOS real opponent of Windows. In this chapter we will describe view Windows as little more than a protected mode version of DOS.

Calling Undocumented DOS from Windows

In Chapter 2 we talked about several ways to write LASTDRV.COM, but each one ended up with a real mode DOS program. Eventually, Department 13 responded to our requests and agreed to turn LASTDRV into a Windows program. This opens a new can of worms that took us some time getting to the DOS internal data structures from protected mode. How do we proceed?

Windows and Printf()

The first problem is what to do with LASTDRV's call to printf(). LASTDRV only needs to produce a single line of output such as "LASTDRIVE=M". The amount of output is exactly the same as that for the classic "hello world" program, so writing the code shouldn't be too hard. However, all the standard books on Windows programming start by teaching you how to display "hello world" in Windows. The source code for this supposedly introductory program invariably takes about 80 lines of code and requires several other source files as well. Just displaying these seven characters in Windows apparently requires calls to RegisterClass(), CreateWindow(), GetMessage(), BeginPaint(), TextOut() and so on, as well as an understanding of the concepts behind each of these key Windows API functions. It seems that by agreeing to Markeching's request to port LASTDRV to Windows, we have bought ourselves a big mess.

To survive as a PC programmer in the 1990s, you really do need to learn those Windows functions. However, that's a ridiculously difficult place to start. The biggest mental stumbling block for DOS programmers attempting Windows is the misconception that to write a Windows program, even the simplest Windows program, you must first learn how to register window classes, create windows, handle messages, and so on.

Well, it just isn't necessary. Not only has Borland with its EasyWin library and Microsoft with QuickWin made it easy to port simple DOS programs to Windows, but even more important, there are Windows API functions which are happy to accept data that you can use them to do an entirely self-contained simple Windows application. "Hello world"? Despite what all the Windows programming books say, it's as simple as calling MessageBox(), well that and using Windows' weird WinMain() entry point instead of the main() entry point that's used everywhere else in the world.

```
/* bcc -WS hello.c */
#include "windows.h"

#pragma argsused
int PASCAL WinMain(HANDLE hInstance, HANDLE hPrevInstance,
    LPSTR lpszCmdLine, int nCmdShow)
{
    MessageBox(0, "hello, world", "My First Program", MB_OK);
    return 0;
}
```

That's it. Furthermore, the Windows MessageBox() function can produce an entire screen of output. Just put carriage returns in the string passed as the second parameter to MessageBox(). This makes it handy for tiny utilities like LASTDRV.

Alternatively, you can take advantage of Windows' multitasking and its interprocess messaging to use another program, such as Notepad, as your "display engine." For example, a Windows program can use the WM_SETTEXT message to blast text into some other window. This message can be sent to the other window with SendMessage(). For example, the following program launches Notepad and then sends the string "hello, world" to Notepad's window. There's no intermediary text file.

```
/* bcc -WS hello2.c */
#include "windows.h"

#pragma argsused
int PASCAL WinMain(HANDLE hInstance, HANDLE hPrevInstance,
    LPSTR lpszCmdLine, int nCmdShow)
{
     if (WinExec("notepad.exe", SW_SHOWNORMAL) < 32)
        return FALSE;
    Yield();
    SendMessage(GetFocus(), WM_SETTEXT, 0,
        (DWORD) (char far *) "hello world");
}
```

Using such primitive capabilities, it is easy to build Windows-specific versions of functions such as printf(). There is nothing magical about printf() or any other stdio function. As EasyWin and Quick Win show, it's possible to build stdio libraries on top of the Windows API. So why isn't there such a facility in Windows to begin with?

PRINTF.C and PRINTF.H in Listings 3.1 and 3.2 provide a rather hokey (one tech reviewer says "a project from a grade") but functional way to do simple Windows utilities like the ones we build in this chapter. A program that wants to use this facility should include "printf.h" and start off with a WinExec() to open a display window. The program can then freely call printf(). In PRINTF.C, printf() simply accumulates text until a call to show displays it. To build a program, just link with PRINTF.C and compile for Windows. For example, in Borland C++ use bcc -W hello.c prntf.c. Microsoft C++ users will need a Windows DLL to do automatic

The show display function normally uses MessageBox(), but if there is more text than will fit in a MessageBox(), PRINTF.C uses WinExec() to bring up a copy of Notepad. PRINTF.C then sends the text to Notepad using the WM_SETTEXT message and the SendMessage() function mentioned earlier. This program does not create an intermediate file; it shoots the text directly to memory in Notepad. Later on in the book, I'll show you how to send text to another shown window. Underneath, Windows is generally message based. Messages are a basic form of interprocess communication, not just an elaborate way of describing a function call.

Listing 3-1. PRINTF.C

```
/*
PRINTF.C - simple output for small Windows programs,
using MessageBox() or WinExec()/SendMessage()
from "Undocumented DOS", 2nd edition (Addison-Wesley, 1993)
*/

#include <stdlib.h>
#include <stdarg.h>
#include <string.h>
#include <windows.h>
#include <stdio.h>      // for vsprintf
#include "printf.h"

#define BUF_SIZE        2048

static char *str, *app,
static unsigned cap, len,
static int lines;

BOOL open_display(char *appname)
{
    app = appname,
    cap = 128;
```

```
    if (! (str = (char *) malloc(cap)))
        return FALSE;
    *str = lines = len = 0;
    return TRUE;
}
/* Maximum number of lines that MessageBox will hold */
static int max_lines(void)
{
    TEXTMETRIC tm;
    HWND hWnd = GetActiveWindow();
    HDC hDC = GetWindowDC(hWnd);
    if (hDC == NULL)
        return 0;
    GetTextMetrics(hDC, &tm);
    ReleaseDC(hWnd, hDC);
    return (GetSystemMetrics(SM_CYFULLSCREEN) /
        (tm.tmHeight + tm.tmExternalLeading)) - 5;
}
BOOL show_display(void)
{
    if (lines <= max_lines())
        MessageBox(NULL, str, app, MB_OK);
    else
        notepad(str);
    free(str);
    return TRUE;
}
static BOOL append(char *s2)
{
    char *s3;
    if (((len += strlen(s2)) < cap) && strcat(str, s2))
        return TRUE;
    cap = len + 128;
    if (! (s3 = (char *) malloc(cap)))
        return FALSE;
    strcpy(s3, str);
    strcat(s3, s2);
    free(str);
    str = s3;
    return TRUE;
}
int nlines(char *s2)
{
    int c, n = 0;
    while ((c = *s2++) != 0)
        if (c == '\n')
            n++;
    return n;
}
int printf(const char *fmt, ...)
{
    static char s2[BUF_SIZE];
    int len;
    va_list marker;
    va_start(marker, fmt);
    // Following uses vsprintf() rather than KERNEL wvsprintf()
    // because wvsprintf() requires that all %s parameters
    // be FAR; e.g., printf("%s\n", (char far *) "hi")
    len = vsprintf(s2, fmt, marker);
    lines += nlines(s2);
    va_end(marker);
    append(s2);
    return len;
```

```
}
BOOL notepad(char far *s)
{
    HWND notepad;
    HWND edit_ctrl;
    if (WinExec("notepad.exe", SW_SHOWNORMAL) < 32)
        return FALSE;
    notepad = FindWindow(NULL, "Notepad - (untitled)");
    edit_ctrl = GetFocus();
    SendMessage(notepad, WM_SETTEXT, 0, (DWORD) (char far *) app);
    SendMessage(edit_ctrl, WM_SETTEXT, 0, (DWORD) (char far *) s);
    return TRUE;
}
#ifdef TESTING
int PASCAL WinMain(HANDLE hInstance, HANDLE hPrevInstance,
    LPSTR lpszCmdLine, int nCmdShow)
{
    int i;
    open_display("GetSystemMetrics");
    for (i=0; i<37; i++)
    {
        printf("%d\t%d\n", i, GetSystemMetrics(i));
        Yield();
    }
    show_display();
}
#endif
```

Listing 3-2: PRINTF.H

```
/* PRINTF.H */
BOOL open_display(char *appname);
BOOL show_display(void);
#ifdef __cplusplus
extern "C"
#endif
int printf(const char *fmt, ...);
BOOL notepad(char far *s);
```

There are several alternatives to using this wordy version of printf. As noted above, Borland C++ comes with an EasyWin option that provides C stdio functions for Windows. To use EasyWin, you just take a DOS program that has main() instead of WinMain() as its entry point and compile for Windows (for example, bcc -W hello.c). To build a program with QuickWin in Microsoft C/C++, compile with the cl -Aq switch. In addition, the book *Undocumented Windows* comes with a more extensive stdio library for Windows, WINIO, which provides many features beyond those in EasyWin or QuickWin, including the ability to write event-driven programs while still using stdio functions.

Once we have some version of printf() for Windows, it is easy to move LASTDRV to Windows. For example, using PRINTF.H (Listing 3.2), we hacked one of the versions of LASTDRV.C from Chapter 2 so it started itself with WinMain() instead of main(). Otherwise, the program does the usual undocumented DOS stuff, including calling INT 21h function 52h and indexing into SysVars. We might as well add a few more pieces of output. The result is a Windows version of LASTDRV.C shown in Listing 3.3. Since so many programs here use the get_sysvars() function, it has been moved into a separate file, SYSVARS.C, in Listing 3.3a.

Listing 3-3: LASTDRIV.C for Windows

```
/* LASTDRIV.C:  bcc -W lastdriv.c printf.c */

#include <stdlib.h>
#include <dos.h>
```

```
#include "windows.h"
#include "printf.h"  // see Listing 3-1, 3-2
void maybe_change_osmajmin(void)
{
    _asm mov ax, 3306h
    _asm xor bx, bx
    _asm int 21h
    _asm or bx, bx
    _asm jz osmajmin_ok
    _asm mov byte ptr _osmajor, bl
    _asm mov byte ptr _osminor, bh
osmajmin_ok:;
}
/* get_sysvars() */
#include "sysvars.c"
#ifdef __cplusplus
extern "C" int PASCAL WinMain(HANDLE hInstance, HANDLE hPrevInstance,
    LPSTR lpszCmdLine, int nCmdShow);
#endif
int PASCAL WinMain(HANDLE hInstance, HANDLE hPrevInstance,
    LPSTR lpszCmdLine, int nCmdShow)
{
    BYTE far *sysvars;
    BYTE lastdrive;
    open_display("LASTDRIVE");
    sysvars = get_sysvars();
    printf("SysVars @ %Fp\n", sysvars);
    maybe_change_osmajmin();
    printf("DOS %u.%02u\n", _osmajor, _osminor);
    lastdrive = sysvars[(_osmajor == 3 && _osminor >= 0) ? 0x1B
                        (_osmajor >= 2) ?                  0x10
                        /* otherwise */                    0x21];
    printf("LASTDRIVE=%c\n", 'A' + lastdrive - 1);
    show_display();
    return 0;
}
```

Listing 3-3a: SYSVARS.C

```
/* SYSVARS.C */
BYTE far *get_sysvars(void)
{
    _asm xor bx, bx
    _asm mov es, bx
    _asm mov ah, 52h
    _asm int 21h
    _asm mov dx, es
    _asm mov ax, bx
    // return value in DX:AX
}
```

Compiling the program for example, LASTDRIV produces results in a Windows executable, LASTDRIV.EXE. Given that the premise of this chapter is that Windows applications must do something special to access undocumented DOS, and given that we have done nothing special here, you would fully expect LASTDRIV to blow up or otherwise do something foolish when it is run in a DOS box under Windows.

Actually, though, LASTDRIV works fine. Figure 3-1 shows that LASTDRIV not only looks like a little Windows program, but the results look reasonable, too. In this configuration, LASTDRIVE=M is the correct answer.

Figure 3-1 Running LASTDRIV Under Windows

It Doesn't Really Work!

LASTDRIV

Listing 3-4 CURRDRIV.C for Windows (Fails!)

```
/* CURRDRIV C:  bcc -W currdriv c printf c */

#include <stdlib h>
#include <dos.h>
#include  windows h"
#include  printf.h"

/* get_sda() */
#include  getsda

BYTE get_doc_currdrive(void)
{
    _asm mov ah, 19h
    _asm int 21h
    _asm xor ah, ah
    // return value in AX
}

void do_currdrive(void)

    BYTE far *sda,
    BYTE currdrive,
    BYTE doc_currdrive,

    sda = get_sda(),
```

```
    printf("SDA @ %Fp\n", sda);
    /* Following line gets wrong results (unless if UNDOSMGR 386,
       which supports 21/5D06 in protected mode, is installed ) */
    currdrive = sda[0x16];
    printf("CURRDRIVE=%c (from SDA)\n", 'A' + currdrive);
    doc_currdrive = get_doc_currdrive();
    if (currdrive != doc_currdrive)
        printf("Something wrong! CURRDRIVE=%c\n",
            'A' + doc_currdrive);
}
#ifdef __cplusplus
extern "C" int PASCAL WinMain(HANDLE hInstance, HANDLE hPrevInstance,
    LPSTR lpszCmdLine, int nCmdShow);
#endif
int PASCAL WinMain(HANDLE hInstance, HANDLE hPrevInstance,
    LPSTR lpszCmdLine, int nCmdShow)
{
    open_display("CURRDRIVE");
    do_currdrive();
    show_display();
    return 0;
}
```

Listing 3-4a: GETSDA.C

```
BYTE far *get_sda(void)
{
    _asm push ds
    _asm push si
    _asm mov ax, 5d06h
    _asm int 21h
    _asm jc error
    _asm mov dx, ds
    _asm mov ax, si
    _asm jmp short done
error:
    _asm xor ax, ax
    _asm xor dx, dx
done:
    _asm pop si
    _asm pop ds
    // return value in DX:AX
}
```

CURRDRIV really does seem just like INSTDRIV. Each program calls an undocumented function, and each program extracts a byte value from a DOS internal data structure whose address the functions returns. While INSTDRIV worked, though, CURRDRIV produces totally wrong results, as Figure 3-2 shows.

Figure 3-2: CURRDRIV Messes Up

Not only are the results wrong (CURRDRIV showed drive A as the current drive, whereas the document function 19h returned C), but running multiple copies of CURRDRIV produces even stranger results. The address displayed for the SDA is different each time. For example, one run of the CURRDRIV showed an address of 1197:0320 for the SDA, whereas Figure 3-2 shows an address of 1387:0320 for the SDA. The segment for which looks wrong, anyhow. The SDA does *not* move around! Something is clearly wrong with the idea that Windows programs can just call any old undocumented DOS function and access any old internal DOS data structure.

At the end of this chapter (see Listing 3-31), we'll write a VxD that changes Windows in such a way CURRDRIV gets correct results. Without this VxD, however, CURRDRIV gets bogus results.

The Dreaded GP Fault

"But I don't ever call INT 21h function 5D06h. I've never used the SDA. The only undocumented DOS function I could see using is Function 52h, and the only structure I'm interested in is SysVars. LASTDRIVE (which showed that Windows won't let you change it) is out of SysVars, right?

Not yet. Next, try grabbing something other than LASTDRIVE out of SysVars. A good example is the pointer to the System File Table chain at offset 4 in SysVars. As Chapter 1 mentions, programs like WINSOM that need to get the value of FILES= reliably usually do so by walking the SFT chain. SFTWALK.C (Listing 3-5) is a real-mode DOS program that uses this technique.

Listing 3-5: SFTWALK.C for Real Mode DOS

```
/* SFTWALK.C -- count FILES= by walking SFTs */

#include <stdlib.h>
#include <stdio.h>
#include <dos.h>

typedef unsigned char BYTE;
typedef unsigned short WORD;

/* get_sysvars() -- see Listing 3-3a */
#include "sysvars.c"

typedef struct _sft {
    struct _sft far *next;
    WORD num;
    // other stuff not used here
    } SFT;

main()
{
    BYTE far *sysvars = get_sysvars();
    SFT far *sft = *((SFT far * far *) &sysvars[4]);
    int files = 0;
    while (FP_OFF(sft) != 0xFFFF)
    {
        files += sft->num;
        printf("SFT @ %Fp    %u files\n", sft, sft->num);
        sft = sft->next;
    }
    printf("FILES=%d\n", files);
}
```

In addition to printing out the FILES= value, SFTWALK also displays the address and number of files for each SFT in the chain. For example:

```
SFT @ 0116:00CC -- 5 files
SFT @ 05E8:0000 -- 40 files
FILES=45
```

This output was correct. In this configuration CONFIG.SYS had FILES 55. However, before we've even turned this into a Windows program, just running the same real mode SFTWALK.EXE in a DOS box under Windows protected mode returns results claiming FILES=55 and showing an extra SFT with 10 entries

```
SFT @ 0116:00CC -- 5 files
SFT @ 05E8:0000 -- 40 files
SFT @ 1295:0004 -- 10 files
FILES=55
```

We will explore this issue later. For now, the curious reader should check out the description of the Windows SYSTEM.INI DeviceMF device setting in a reference such as the *Windows Resource Kit groups Resource Kit*.

To start porting SFTWALK.C to Windows, we start with the following DefWinProc requires no change to the source code, merely recompile with the new Windows.h. Of course, you can read SFTWALK.C to use PRINTF.C from Listing 3-1 if it makes you feel better.

Either way, when the Windows version of SFTWALK runs it doesn't work as the command-line version. LASTDRIV did. Nor does it even produce incorrect results the way CURRDRIV did. Instead, SFTWALK bombs, producing a general protection violation error (GP Fault) as Figure 3-3 shows. In Windows 3.0, the message refers instead to an Unexpected Application Error (the decoded UAE).

Figure 3-3: Windows Version of SFTWALK GP Faults

```
Application Error
SFTWALK caused a General Protection Fault in
module SFTWALK.EXE at 0001:01A4.
```

If SFTWALK is compiled with debugging symbols and run under a debugger such as Turbo Debugger or Soft-ICE/Windows, WINICE, the debugger catches the GP Fault and highlights the offending code in SFTWALK.C

```
*files += sft->num;

les bx, [bp-8]
add cx, es:[bx+4]   , GP fault occurs here!
```

The GP fault is just an interrupt (INT 0Dh) in the microprocessor sends to an application which has violated one of the many rules of the road in protected mode. Protected mode is the processor mode protected mode in the first place. For example, segments in protected mode are specific sizes, and if a program reads or writes memory past that size, the processor decides that the program has violated protection and issues a GP Fault.

One rule of protected mode is that you may not put any arbitrary number into a segment register. It must be a special number called a *selector*. A selector corresponds to a processor data structure called a *descriptor*. Most descriptors are generated by the OS and describe real memory addresses and lengths. The descriptor is then loaded into a segment register such as ES, with GP fault. Descriptors are created by the OS in such a way that most numbers *don't* point to legal descriptors. This is done because the descriptor space is sparse. This is helpful when the protected mode OS wants to protect its own processes. Random numbers pulled out of a hat and used as selectors are highly probable to cause GP faults. Random numbers from a hat and used as pointers are highly probable to cause GP faults. In practice, though, this protection works pretty well. In contrast to the havoc it would wreak in real mode, the following insane program (99.44 100% likely) is safely terminated with a GP fault in protected mode.

```
main()
{
    unsigned char far *fp;
    for (;;)
    {   // see Listing 2-10 for MK_FP()
        unsigned far *fp = MK_FP(rand(), rand());
```

```
        *fp = 666;
    }
}
```

The lesson is that protected mode pointers must correspond to descriptors. These descriptors are [illegible] maintained generally by an operating system such as Windows and used by the hardware when a new value is loaded into a segment register. A descriptor contains information about a segment such as the specified size of the segment. The size actually is stored as the *limit* that is [illegible] the last valid byte offset within the segment. Besides the segment's size, a descriptor also defines a segment's attributes: code, data, read, write, and so forth—and its *base address*.

Descriptors, base addresses, and limits fill this chapter. We will rely on it heavily to get to undocumented DOS data structures from protected mode. Recall that a real mode address was always expressed as the segment value:offset. For example, 1001:0000 is so that 1001:0000, for example, points to the location 10010. Protected mode introduces a small but drastic change. There are still [illegible] pointers, but the first part means something entirely different.

Protected mode pointers do not have a direct correspondence to memory addressing. A selector value such as 0008, for example, is an index into a descriptor table. This value is not in any way related to physical memory location 0008h. Actual memory addresses are instead stored inside the descriptor in the base address field. If you actually wanted to get to a memory location such as 1000:0, a protected mode pointer such as 0008:0000 would do you absolutely no good at all. Instead, you would need a selector whose descriptor had a *base address* of 10000h. The value of the selector itself is irrelevant. Remember, the selector only represents an index into a descriptor table.

Each segment in protected mode actually has a base address that is not necessarily a physical memory address, that is a value that the processor can put on the address bus. In paging, as used on the 80386 or higher, it is instead a *virtual address*. This corresponds to yet another set of tables and yet another level of indirection. Page tables contain [illegible] physical address or an indication that a page is not present. This is the basis of virtual memory. (See Robert Hummel, "Extending Protected Pageable Memory for Windows Enhanced Mode," *Windows Developer's Journal*, December 1992.)

Fortunately, DOS and Windows are transparent. Programs that access the segment registers just like in real mode, and the processor takes care of the conversion to the correct part of memory. It is also fortunate that there exists a [illegible] tool that the processor contains several caches, which are used to [illegible] address tables every time you read or write memory.

Several [illegible] programs, LANGDRIV, CURRDRIV, and SETWALK, all do more or less [illegible] yet [illegible] all different results. LANGDRIV works properly. SETWALK GP faults, and CURRDRIV "works" but in fact produces bogus results. What can we conclude about the Windows DOS extender support for undocumented DOS?

- LANGDRIV assumes that SysVars pointer must be valid. The program didn't GP fault, so SysVars is [illegible] a protected mode pointer. INT 21h AH=52h returned this pointer, so in Windows protected mode, INT 21h must return a protected mode pointer to SysVars.
- CURRDRIV doesn't GP fault, so the SDA pointer must at least be legal. It's a legitimate protected mode pointer, but the results are bogus. Conclusion: it must actually point, not to the SDA, but to some other [illegible]. Thus, INT 21h AX=5D06h in Windows protected mode returns protected mode pointers that point to SysVars.
- SETWALK GPs because the SDA pointer is invalid in protected mode. That means it must [illegible] a real mode pointer. But we got this pointer out of SysVars, to which INT 21h AH=52h returned a valid protected mode pointer. Conclusion: in Windows protected mode, INT 21h AH=52h returns a protected mode pointer to SysVars, but any pointers inside SysVars itself are still real mode and will need to be translated.

The implications of the earlier discussion of descriptors and selectors for getting at undocumented DOS data structures from protected mode Windows should now be clear. To get at the SFT, for instance, you can't load the real mode address of the SFT into ES:BX and expect it to work. Instead you must allocate a descriptor, put the real mode address of the SFT into the descriptor's base address field, and then use whatever selector corresponds to that descriptor as the sss portion of your protected mode sss:xxxx pointer. We're getting a couple jumps ahead of ourselves here, but the Windows API has the function AllocSelector() allocates both a descriptor and a selector, the formerly undocumented function SetSelectorBase() sets the base address. We will be relying heavily on these functions in this chapter.

A DPMI Shell

To gain a better understanding of what's going on and what we can do about it, let's forget about Windows programs for a moment and look at DPMI programming. Using the DPMI services that Windows' Enhanced mode provides, real mode DOS programs can switch into protected mode. While Windows Standard mode also provides DPMI, it is only accessible to Windows programs, not to programs running in the Standard mode DOS box. Memory managers such as 386MAX and such add-ins, QEMM, also provide DPMI services.

Before we launch into using DPMI, it's worth looking at an error in the Microsoft Windows SDK documentation. The very brief SDK discussion of DPMI, "Windows Applications and MS-DOS Functions," *Programming Reference, Volume 1*, Chapter 20, states that Windows 3.0 and later support DPMI 0.9. This is not true. Both Windows 3.0 and 3.1 support version 0.9 of the DPMI specification. Further, none of the DPMI 0.9 functions are supported except in Standard mode. On the other hand, Enhanced mode does support a few DPMI 1.0 functions not commonly available via INTs. The SDK also claims that all seven DPMI functions are required for Windows applications. This certainly is not true. What's more, to match the functionality we need here are stable across all the different DPMI implementations.

We can use DPMI to take us DOS versions of LANTDRIV, CURRDRIV, and INSTWATCH and execute them in protected mode. In programs in protected mode and stacking, the character ends DOS, we can separate the Windows specific services from its more correct protected mode services. Comparing the behavior of the protected mode DOS versions of these programs with the behavior of the Windows versions also serves as a good introduction to what's different about Windows.

A normal real mode DOS program can't just switch into protected mode and issue a DPMI call. INT 2Fh AX=1687h. Moreover, the DPMI specification requires that the program first call INT 2Fh AX=1686h to test for the presence of DPMI, which makes this call and then calls the entry point it returns. The program can now switch using DPMI services. In DPMISHELL (Listing 3-6), main() calls a function, check_dpmi(), that accesses DPMI, tests if it is in protected mode, and then calls pmode_main(). DPMISHELL expects an application such as LANTDRIV to supply real_main() and pmode_main() and to #include DPMISHELL.H (see Listing 3-7). Besides DPMISHELL, the program also needs to link with CTRL_C.ASM, a tiny assembly language module which assists with Ctrl-C handling (see Listing 3-8).

Listing 3-6: DPMISH.C

```
/*
DPMISH.C
Shell to run a simple C program in protected mode under DPMI
Andrew Schulman, February 1993
from  Undocumented DOS , 2nd edition (Addison-Wesley, 1993)
(Changed version of DPMISHEL, from MSJ, Oct. 1992, Dec  1992)

Does Ctrl-C handling; see CTRL_C.ASM
Must be compiled small model to use C run-time library
Calls real_main(), switches into protected mode, then calls pmode_main()

To build a DPMI app:
```

```
bcc -2 -DDPMI_APP foo.c dpmish.c ctrl_c.asm
*/

#include <stdlib.h>
#include <stdio.h>
#include <dos.h>
#include "dpmish.h"

void _dos_exit(int retval)
{
    _asm mov ah, 04ch
     asm mov al, byte ptr retval
    _asm int 21h
}

/* Call the DPMI Mode Detection function (INT 2Fh AX=1686h) to see
// if we are *already* running in protected mode under DPMI.
/  See 3.1 DDK _Device Driver Adaptation Guide_, pp. 585-586
int dpmi_present(void)
{
    unsigned _ax;
    _asm mov ax, 1686h
     asm int 2Fh
    _asm mov  ax, ax /* 2F/1686 ret 0 if DPMI is present */
    return (! _ax);  /* turn it around so 0 if *not* present */
}

// Call the DPMI function for Obtaining the Real to Protected Mode
// Switch Entry Point (INT 2Fh AX=1687h), to determine if DPMI is
// available and, if so, switch into protected mode by calling
// the Switch Entry Point. See DPMI 0.9 spec.
int dpmi_init(void)
{
    void (far *dpmi)();
    unsigned hostdata_seg, hostdata_para, dpmi_flags;
    _asm push si
    _asm push di
    _asm mov ax, 1687h          /* test for DPMI presence */
    _asm int 2Fh
     asm and ax, ax
    _asm jz gotdpmi             /* if (AX == 0) DPMI is present */
    _asm jmp nodpmi
gotdpmi:
    _asm mov dpmi_flags, bx
    _asm mov hostdata_para, si  /* paras for DPMI host private data */
    _asm mov word ptr dpmi, di
    _asm mov word ptr dpmi+2, es /* DPMI protected mode switch entry point */
     asm pop di
    _asm pop si
    if ( dos_allocmem(hostdata_para, &hostdata_seg) != 0)
        fail("can't allocate memory");

    dpmi_flags &= 1,    /* this is a 16-bit protected mode program */

    /* enter protected mode */
     asm mov ax, hostdata_seg
    _asm mov es, ax
    _asm mov ax, dpmi_flags
    (*dpmi)();
    _asm jc nodpmi    /* carry set if error */
    /* in protected mode now   segment registers changed! */
    return dpmi_present();   /* double check */
nodpmi:
    return 0;
}

void dpmi_setprotvect(int intno, void (interrupt far *func)(void))
```

```
{
    _asm mov ax, 0205h
    _asm mov bl, byte ptr intno
    _asm mov cx, cs     /* word ptr func+2 */
    _asm mov dx, word ptr func
    _asm int 31h
}
// INT 23h handler under DPMI can't do the usual DOS INT 23h stuff
// needs to be on page locked with 31/0600??
// problem:  compiler has hard-wired (real mode)  (oadds'
#if 1
// pull in CTRL_C.ASM (Listing 3-8)
#ifdef __cplusplus
extern "C" void interrupt far ctrl_c(void),
#else
extern void interrupt far ctrl_c(void),
#endif
#else
int ctrl_c_hit = 0;
void interrupt far ctrl_c(void)
{
    ctrl_c_hit++,
}
#endif
main(int argc, char *argv[])
{
    int ret,
    // actually, if already in pmode, real main() still runs
    // (this is for debugging under 286|DOS-Extender)
    if (real_main(argc, argv) != 0)
        return 1,
    flushall(), // flush all buffers before switch into protected mode
                // so I/O redirection works properly

    if (dpmi_present())
        printf("Already in protected mode\n");
    else if (dpmi_init())
        printf( Switched into protected mode via DPMI\n"),
    else
        fail("This program requires DPMI"),

    // now in protected mode, segment registers have changed

    dpmi_setprotvect(0x23, ctrl_c), // install Ctrl-C handler
    ret = pmode_main(argc, argv),   // call the application's pmode_main
    flushall(),                     // flush all buffers before exiting
     dos_exit(ret),                 // must exit via 21 4C'
}
```

Listing 3-7: DPMISH.H

```
/*
DPMISH.H -- see DPMISH.C
Andrew Schulman, February 1993
from 'Undocumented DOS', 2nd edition (Addison-Wesley, 1993)
*/

#ifdef __BORLANDC__
#ifndef __SMALL__
#error DPMISH requires small model
#endif
#else /* Microsoft C */
#ifndef M_I86SM
#error DPMISH requires small model
```

```
#endif
#endif
#ifndef DPMI_APP
#define DPMI_APP
#endif

#ifdef   BORLANDC__
#define  dos_allocmem(x,y)  (al_ocmem(x,y)  - 1
#endif

void  dos_ex t  nt retval),
int dpmi_present void),
int dpmi_init void ,

 * unfortunately, the app has to check Ctrl C itself */
extern int ctrl_c_hit,

/* these functions must be defined by app */
extern int real_main(int argc, char *argv[]),
extern  i  pende main(int argc, char *argv[]
extern void fail(const char *s, ...);  // app's fail() must call _dos_exit()
```

Listing 3-8: CTRL_C.ASM

```
; CTRL_C.ASM — for use with DPMISHEL

dosseg
 model small

public _ctrl_c_hit
public _ctrl_c

 data
_ctrl_c_hit dw  0

 code
_ctrl_c proc far
    inc _ctrl_c_hit   ; using app's DS
    iret
_ctrl_c endp
end
```

[illegible]

Listing 3-9: DPMITEST.C

```
/*
DPMITEST.C
bcc -DDPMI_APP -2 dpmitest.c dpmish.c ctrl_c.asm

Sample output
CS=165Ch DS=1705h
Switched into protected mode via DPMI
CS=0097h DS=008Fh
*/
#include <stdlib.h>
#include <stdio.h>
#include <dos.h>
#include  dpmish.h"
void print_regs(void)
{
    struct SREGS s;
    segread(&s);
    printf("CS=%04Xh DS=%04Xh\n", s.cs, s.ds);
}
void fail(const char *s, ...)           { puts(s), _dos_exit(1); }
int real_main(int argc, char *argv[]);  { print_regs(), return 0; }
int pmode_main(int argc, char *argv[])  { print_regs(), return 0; }
```

Naturally, the new protected mode selectors that DPMI creates and loads into CS, DS, and SS on the program's behalf have new addresses that correspond to the program's original real mode segment addresses. In the output from DPMITEST shown at the top of Listing 3-9, selector 0097h happened to have a base address of 1650h, and selector 008Fh had a base address of 1550h. You can verify this in WINDEBUG or some other debugger with the DPMI selector Segment Base Address function (INT 31h AX=6). By contrast, a DPMISH code segment pseudo-mode-switch on the program is running in protected mode. The overall memory model of DPMISH is very much like that of a Windows program, except that the program's character pools and the internal versions of functions such as printf() and fopen() have DPMISH in their names to avoid conflicts with libraries such as EasyWin, QuickWin, and WINIO, or the case of conflicts with Windows printf() from the MessageBox() function.

But the DPMISH program calls C runtime library routines only at the compiler's small model. Many of these library routines end up making INT 21h calls directly into Windows' protected mode DOS extender. DPMISH's simple assumption is the presence of DPMI, so these calls to protected mode INT 21h are present. This quasi-upmode assumption is also used to our practical works. But with small modifications, as we'll see near the program's end, DPMISH is going to have its segment registers changed out from under it, the program cannot long continue to use pointers after executing the *dpmi* call to switch into protected mode. The C runtime library undoubtedly does hang onto pointers to buffers and stacks set up under the small model. In these cases, these won't be far pointers with segments in them that will become invalid after the jump into hyperspace (oops, protected mode).

Trying Out Undocumented DOS from DPMISH Programs

We now take the Windows version of LASTDRIV and modify it to also run under DPMISH. We take the code that LASTDRIV executes inside of WinMain() or main() and move the code to a separate function, dos_lastdrive(). The DPMI API version of LASTDRIV then calls dos_lastdrive() from both real mode and protected mode. Listing 3-10 shows this new version of LASTDRIV.

Listing 3-10: LASTDRIV for DPMI or Windows

```
/*
LASTDRIV.C
```

```
Windows:  bcc -W lastdriv.c printf.c
DPMI.     bcc -DDPMI_APP -2 lastdriv.c dpmish.c ctrl_c.asm
*/

#include <stdlib.h>
#include <dos.h>
#ifdef DPMI_APP
#include <stdio.h>
#include "dpmish.h"

typedef unsigned char BYTE;
#else
#include "windows.h"
#include "printf.h
#endif

void maybe_change_osmajmin(void)
{
    _asm mov ax, 3306h
    _asm xor bx, bx
    _asm int 21h
    _asm or bx, bx
    _asm jz osmajmin_ok
    _asm mov byte ptr _osmajor, bl
    _asm mov byte ptr _osminor, bh
osmajmin_ok :
}

/* get_sysvars() -- see Listing 3-3a */
#include "sysvars.c"
void do_lastdrive(void)
{
    BYTE far *sysvars;
    BYTE lastdrive;
    sysvars = get_sysvars();
    printf("SysVars @ %Fp\n", sysvars);
    maybe_change_osmajmin();
    printf( DOS %u.%02u\n , _osmajor, _osminor);
    lastdrive   sysvars[( osmajor == 5 && _osminor >= 0) ? 0x18 :
                        (_osmajor == 2) ?                  0x10 :
                        /* otherwise */                    0x21];
    printf("LASTDRIVE=%c\n", 'A' + lastdrive - 1);
}

#ifdef DPMI_APP
void fail(const char *s,   .) { puts(s), _dos_exit(1), }

int real_main(int argc, char *argv[])
{
    printf("In real mode:\n");
    do_lastdrive();
    printf("\n );
    return 0;
}

int pmode_main(int argc, char *argv[])
{
    printf("In protected mode:\n"),
    do_lastdrive();
    return 0;
}
#else
// Windows program
#ifdef __cplusplus
extern "C" int PASCAL WinMain(HANDLE hInstance, HANDLE hPrevInstance,
    LPSTR lpszCmdLine, int nCmdShow),
#endif

int PASCAL WinMain(HANDLE hInstance, HANDLE hPrevInstance,
```

```
    LPSTR lpszCmdLine, int nCmdShow)
{
    open_display("LASTDRIVE"),
    do_lastdrive();
    show_display(),
    return 0;
}
#endif
```

The DPMI version of LASTDRIV works just as the Windows version did. There seems to be some commonality between Windows programs and protected mode DOS programs. But what is the DPMI version of LASTDRIV gets the same correct LASTDRIVE. Mainly because communicating from real mode to the address (via INT 21h function 52h) returns for SysVars in protected mode is different. The program's output looks like this:

```
C:\JNDOC2\CHAP3>lastdriv
In real mode:
SysVars @ 0116 0026
DOS 6.00
LASTDRIVE=M

Switched into protected mode via DPMI
In protected mode:
SysVars @ 00AF.0026
DOS 6.00
LASTDRIVE=M
```

Note that SysVars was located at 0116:0026 in real mode but at 00AF:0026 in protected mode. Did SysVars move? No, of course not. Instead this is just another confirmation of what you saw before. INT 21h function 52h in Windows returns a protected mode pointer to SysVars. It is debugger-ready as WINICE is used to port LASTDRIV. You can see that 00AF is in fact a protected mode selector with the base address of 1160h. In other words, it addresses exactly the same memory as real mode pointer 0116:0026. Below, LDT is the WINICE command for inspecting selectors. LDT refers to the Local Descriptor Table.

```
:ldt 00af
00AF   Data16   Base=00001160   Lim=0000FFFF   DPL=3   P   RW
```

We can also use DPMINFO to run LRRDRIV in protected mode DOS program. It's not worth showing the code here because DPMINFO works in Listing 3-4 in the same way that Listing 3-3 relates to Listing 3-2. We just stuck the code in WinMain so that passes control.

Run protected mode DOS version of LASTDRIV gets an incorrect answer just like Windows version did. Oddly enough, it's similar to what happened when I ran real LRRDRIV under different DPMI server such as SWSMAN 6.0. The important lesson here and one of the long detours into DPMINFO is that protected mode DOS programs running under Windows behave just like character mode Windows programs. The environment for protected mode DOS programs in DPMINFO is a lot like WinMain. A DPMINFO program or any other DOS program that switches itself into protected mode with INT 21h AX=1687h is a lot like a character mode Windows program. Call this around the point is to say that *Windows programs are neither more nor less protected mode DOS programs*. Windows is just a protected mode extension to DOS. Still wondering why we're talking so much about Windows in a book on DOS?

The Windows DOS Extenders

Since MS DOS is not a protected mode operating system, how can there ever be several things to protected mode DOS programs. The division of a protected mode version of DOS must be *taken*.

Let's look at the role of the DOS extender. In Windows Enhanced mode, the DOS extender is contained in the DOSMGR.VxD, which we discussed at length in Chapter 1 and which makes sure

WAY use of undocumented DOS. The DPMI server in Enhanced mode—that is, the code that services function calls such as INT 2Fh AX=1687h and the DPMI INT 31h API—is provided by the Virtual Machine Manager (VMM and DOSMGR are both part of WIN386.EXE; DOSX.EXE in Chicago). In Standard mode, DOSX.EXE contains both the DOS extender and the DPMI server.

The documentation for the DOS extenders in Windows is the scant four-page chapter on "Windows Applications with MS-DOS Functions" in the Windows 3.1 SDK *Programmer's Reference, Volume 1: Overview*. Evidently in the large, inaccurate description of DPMI noted earlier, the documentation also provides a too-short list of DPMI functions available to Windows programs. This chapter then lists both "unsupported" and "partially supported" DOS functions. The section on partially supported functions contains some important notes about DOS 3.1 calls. INT 21h AH=44h. There is no mention of any support—full or partial—for undocumented DOS/BIOS functions. No mention is made one way or the other of important DOS-based services such as MSCDEX. The documentation does make the important point that "if a software interrupt function accepts register-based logical addresses, pointers, segment registers, or stack parameters, then it cannot be used with Windows protected mode."

Besides the SDK documentation there is an external Microsoft document, "MS-DOS API Extensions for DPMI Hosts" (October 31, 1990), which devotes about thirty pages to this same subject. The SDK chapter on the MS-DOS appears to have been boiled down from this more extensive document. For example, the 1990 document discusses 32-bit DOS extenders. The DOS file read and write calls (INT 21h AH=3Fh and 40h) have the count register (ECX) extended to 32 bits, allowing 32-bit programs to perform DOS I/O directly into the 64K bytes at a time. The Enhanced mode DOS extender provides the 32-bit support—one of our tech reviewers tells us this 32-bit support is "totally buggy." The document also discusses the Ctrl-Break (INT 23h) and critical error (INT 24h) handlers under Windows. There is even a rudimentary discussion of ROM-BIOS functionality, including low-level disk access (INT 13h) in protected mode. Microsoft should update this documentation for Windows 3.1 and make it available to developers.

One of the great mysteries—related to the Windows DOS extenders we're on our own trying to figure out—is what they support. How could you take protected-mode DOS. One good test, of course, what makes memory-based services (the DOS supports. From LASTDRIV and CURRDIRV we've gathered that Windows supports Int 21h AH=52h in protected mode and does not support Function 5D06h. But how can we know? And what does "support" and "not support" mean here, anyway?

The program UNDOC.C helps clarify this question. UNDOC can be built as a Windows program (easily from Quick-Win or WINIO, or hacked together to use PRINTF.C from Chapter 4). The program tries to print out the addresses of some important DOS internal data structures (or internal functions). INT 21h functions, as found within SysVars:

Listing 3-11: UNDOC.C

```
/* UNDOC.C */
#include <stdlib.h>
#include <dos.h>
#include <stdio.h>

/* get_sysvars()    see Listing 3-3a */
#include "sysvars.c"

void far *get_sft(void)
{
    unsigned char far * far *sysvars = get_sysvars();
    return *(sysvars+1);    // sysvars[4]
}

void far *get_dpb(void)
{
    unsigned char far * far *sysvars = get_sysvars();
    return *sysvars;        // sysvars[0]
}
```

```
void far *get_cds(void)
{
    unsigned char far *sysvars = (unsigned char far *) get_sysvars();
    return *((void far * far *) &sysvars[0x16]);
}
/* get_sda() -- see Listing 3-4a */
#include "getsda.c"
unsigned char far *get_indos(void)
{
    _asm mov ah, 34h
    _asm int 21h
    _asm mov dx, es
    _asm mov ax, bx
}
main()
{
    printf("SysVars @ %Fp\n", get_sysvars()),          // supported'
    printf("CDS @ %Fp\n", get_cds());
    printf("SFT @ %Fp\n", get_sft());
    printf("DPB @ %Fp\n", get_dpb());
    printf("SDA @ %Fp\n", get_sda());                  // not'
    printf( InDOS @ %Fp\n , get_indos()),              // now doc'
    if (get_indos() != (get_sda() + 1))
        printf( Something funny with SDA and InDOS!\n"),
    return 0,
}
```

Figure 3-4 shows output from UNDOC. Because the InDOS flag is kept at offset 1 relative to SDA, the address that get_sda() (INT 21h, AX = 5D06h) returns should be one less than the address get_indos() (INT 21h, AH = 34h) returns. InDOS, a function 34h, which returns the address of the InDOS flag, was fairly documented in DOS 3.0. See Chapter 4. It is reasonable to expect that the Windows DOS extender would support this function, but UNDOC's output shows that the get_sda() and get_indos() return values are not consistent. As we suspected, Windows doesn't support Function 5D06h.

Figure 3-4: UNDOC Under Windows

```
SysVars = 1007:0026
CDS = 0682:0000
SFT = 0116:000C
DPB = 0116:1368
SDA = 1E67:0320
InDOS = 1007:0321
Something funny with SDA and InDOS!
```

That UNDOC is also unsuccessful in extracting values from SysVars indicates that, as noted, neither get_sysvars() (INT 21h, AH = 52h) nor its returning a valid protected mode pointer. The pointers that UNDOC displays after SysVars, however, look like real mode pointers. The WINICE debugger confirmed, for example, that the CDS was at 0682:0000. The level of support for Function 52h is, of necessity, somewhat uneven.

Notice, however, that whatever the level of support Windows provides for the functions that UNDOC calls, the program does not GP fault. A GP fault occurs when you dereference an invalid pointer. UNDOC *displays* some pointers which are invalid in protected mode, but does not *dereference* them, there is a difference between "displaying" and "using."

It is instructive to run UNDOC in Enhanced mode, under the debug version of Windows. Recall from Chapter 1 that Windows Enhanced mode sets up WIN386.EXE, which is a collection of VxDs. The Enhanced mode DOS extender is part of the DOSMGR VxD, which you can see being loaded in WIN386.EXE. The Windows Device Driver Kit contains a debug version of WIN386, which displays

[illegible] messages and which is newer than the retail version of WIN386. If you run CNDOC under the debug WIN386 and try to run Windows under a low-level debugger such as WINICE or Microsoft's WDEB386 the DOSMGR DOS extender issues the following message:

```
WARNING  DOS INT 21 call  AX=5006 will not be translated
         Use of this call is not supported from Prot
         mode applications
```

DOSMGR uses bypasses this message if you run a protected-mode version of the CURRDRV program (CURRDRV.EXE) that was built with a Borland C++ compiler even *emptied* CNDOC C or any other program that produces this same message. It turns out that Borland C++ assumes that all DPMI hosts support INT 21h AX=5006h in protected mode. It is not clear why Borland calls this function—if Windows is functioning the wrong, all it. Perhaps this is why Borland C++ [illegible] Windows and DOS. Windows is not the DPMI host. As Crowe says, "Actually, [illegible] Windows does not hook the protected-mode interrupt handlers."

Whatever the reason, Borland C++ makes a critical [illegible] assumption—that DPMI provides support for INT 21h AX=5006h in protected mode. When running under DPMI it assumes that all of INT 21h is supported in protected mode. But protected-mode INT 21h is not part of the DPMI specification; it is specific to the DOS extender that is sometimes very [illegible] different from a DPMI server. As noted [illegible] Windows Enhanced mode the DPMI server is the VMM, and the DOS extender is in DOSMGR.386. [illegible] Borland C++ under the debug WIN386 also produces many occurrences of the [illegible] error. If DOS [illegible] is not supported, [illegible] why apparently BC++ is making INT 21h calls in protected mode too (why?).

In practice, it is a fairly reasonable assumption that the presence of DPMI means that you also have protected-mode INT 21h. As we saw, DPMISH.ASM makes this assumption, which is why you [illegible] Clipper programs [illegible] and other C compilers' library functions that depend on INT 21h [illegible] in the protected mode. For example, calling printf() in protected mode causes [illegible] the DOS Write function (INT 21h AH=40h). The Windows DOS [illegible] services in protected mode—even if this function. DPMISH and Borland C++ simply [illegible] that [illegible] Borland C++ [illegible] function 5006h. In most the most part this assumption is valid [illegible] Windows.

[illegible] assumption. As we will see in more detail shortly, DPMI provides services such as INT 31h AX=0300h, Simulate Real Mode Interrupt, to call down to real mode. Any program that uses DPMI services to assume there is [illegible] support for INT 21h in protected mode can instead call INT 21h in real mode. For example, the DOS call for *Undocumented DOS* uses INT 31h to [illegible] DPMI. [illegible] DPMI, but CDDPMI.EXE is actually far more cautious than [illegible] DPMISH. Before [illegible] the Clear Enhancements prompt and then reverts on [illegible] DOS extender in Windows. CDDPMI.C included the functions [illegible] prompt [illegible] which called down to real mode INT 21h using INT 31h AX=0300h.

Given the [illegible] Microsoft's documentation for the Windows DOS extenders, it is probably a [illegible] to [illegible] and more protected mode [illegible] INT 21h functions that Microsoft [illegible] DPMI [illegible] officially supported. This would mean that even though our [illegible] [illegible] Chapter 3's [illegible] work, it would be safer not to trust this function. We will [illegible] earlier version of get_sda() later in this chapter (see Listing 3.18). Certainly, get_sda() *must* be changed (see Listing 3.2)!

Inside the DOSMGR DOS Extender

But how can we find out exactly what function one of the Windows DOS extenders supports? We have [illegible] several [illegible] enough. How can we actually see what the Windows DOS extender is doing? Breaking at the code, of course! In Chapter 1 we examined the DOSMGR VxD to see

which undocumented DOS functions it calls. You can also see which protected-mode interrupt DOS calls it supports and how. This will help determine what you can't do in support of your program for Standard mode, or would need to emulate. DOSX.EXE here, as I have mentioned, is the Enhanced mode DOS extender, DOSMGR. As in Chapter 1, DOSMGR is investigated using the author's Windows Source products from WAGNARDSOFT.

DOSMGR is a new 32-bit protected-mode code running at Ring 0, which is the highest privilege level. Windows applications making INT 21h calls enter this code and are executed at Ring 0 and not at Ring 3 which is the lowest privilege level. This is a very important point to understand. How does DOSMGR arrange to switch to protected mode INT 21h handler when a Windows program opens a file, for example?

Among the many things it does during the Init Critical Internal DOSMGR installs a protected mode INT 21h handler using the VMM Set_PM_Int_Vector function. The address DOSMGR passes to Set_PM_Int_Vector is a callback which points to the PM INT 21h handler in protected mode. I also got going by examining the code in the VxD Assembly Listing 3-7. The VMM Allocate_PM_Call_Back function creates this callback.

Listing 3-12: Installing the Enhanced Mode DOS Extender

```
06F5C       mov eax, 21h                ; INT 21h
06F71       mov esi, PM_INT21           ; address of DOS extender (see Listing 3-13)
06F76       call    SetPMIntVect        ; PM = protected mode

;  *
   SetPMIntVect
06F8B       mov edx,eax                 ; reference data  21h
06F8D       VMMCall Allocate_PM_Call_Back
06F93       mov ecx,eax                 ; segment:offset of callback
06F95       xchg    eax,edx             ; EAX  interrupt number  21h)
06F96       movzx   edx,dx              ; EDX = handler offset
06F99       shr ecx,10h                 ; CX  handler segment
06F9C       VMMCall Set_PM_Int_Vector
```

The protected-mode INT 21h handler for DOSMGR installs is the one we'll be concerned with in a Windows program. If a DOS program is running in protected mode, the DPMIINT.386 driver always makes an INT 21h call. As shown in Listing 3-13, the code in this handler PM_INT21 is very simple.

Listing 3-13: The Enhanced Mode DOS Extender

```
        PM_INT21
00C48       VMMCall Simulate_Int
00C4E       movzx eax, [ebp.Client_AH]              ; get INT 21h func #
00C52       cmp eax, 6Ch                            ; is it one we know?
00C55       ja short UNKNOWN_FUNC
00C57       movzx edx, byte ptr FUNC_TYPE[eax]      ; get func type
00C5E       mov edx, dword ptr XLAT_MACRO[edx*4]    ; get V86MMGR script
00C65       VxDCall V86MMGR_Xlat_API                ; run the script
00C6B   UNKNOWN_FUNC
00C6B       mov edx, INT21_DEFAULT                  ; default script
00C70       VxDCall V86MMGR_Xlat_API                ; run the script
```

In other words, the DOSMGR protected-mode INT 21h handler checks to see if the function number specified in AH is valid. If it is, DOSMGR uses the AH function number as an index into the first of two tables. This first table groups the DOS functions into different categories according to their input and output register usage. The functions' signatures, that is, whether or not they need special treatment.

For example, functions 39h (Create Directory), 3Ah (Delete Directory), and 3Bh (Open File) all take strings in DS:DX, can return values in AX, as well as the carry flag. DOSMGR has also pre-

protected mode calls to all three functions in the same way. It takes the string from DS:DX, copies it to a transfer buffer in conventional memory, switches to real mode (actually V86 mode), puts the real mode address of the transfer buffer into DS:DX, executes the INT 21h call, and then jumps back to protected mode. Given that the many different INT 21h functions actually require only a handful of different ways to treat them, it makes sense to classify them according to type. This is very similar to what one would do in a Remote Procedure Call (RPC) over a network. In many ways, writing a DOS extender is similar to RPC programming.

DOSMGR then takes this INT 21h function type and uses it to index into a second table, which points to translation macros. The V86MMGR.VxD (also part of WIN386.EXE) provides an API translation service documented in the Windows DDK, which helps build DOS extenders and other API translation "translators." The V86MMGR service is actually a set of script macros defined in the V86.DDK header file V86MMGR.INC, and the V86MMGR Xlat API function is a little interpreter that executes these script macros. They were developed by Microsoft. V86MMGR also provides access to the buffer (called the Xlat buffer) in conventional memory. The SYSTEM.INI (386Enh) XlatBufSize setting (undocumented in the *Hardware Reference Kit*) controls the size of this buffer; its default size is 8k bytes (4k in Windows 3.0).

DOSMGR uses V86MMGR Xlat API script macros to implement the DOS extender. The DOSMGR Init code uses these macros for example to support INT 13h disk calls in protected mode. As a simple example, consider a function that requires no special handling, such as INT 21h AH=30h (Get Version). DOSMGR can just take this call passed down ("reflected") to DOS. DOSMGR does so using the following very simple V86MMGR macro:

```
Xlat_API_Exec_Int 21h
```

V86MMGR.INC defines Xlat_API_Exec_Int like so:

```
Xlat_Exec_Int EQU 000h

Xlat_API_Exec_Int MACRO Int_Number
    db Xlat_Exec_Int
    db Int_Number
    ENDM
```

Later, the DOS extender reads for the default INT 21h handler's segment:offset two bytes (00h, 21h), the address which DOSMGR passes to V86MMGR Xlat_API. These macros can make disassembly of DOSMGR a bit difficult, however. V86DEBUG.INT includes a Xlat_API.SYM file that translates these macros.

What does V86MMGR Xlat_API do with it? It reads two bytes. It uses the first one as an index into a table of small code snippets, moves it past the first byte, leaving the specific handler to deal with any extra bytes. It then calls the handler with a "return" hit:

```
    V86MMGR Xlat_API    proc near
00158   push    eax                 ; EDX = pointer to script
0015C   movzx   eax,byte ptr [edx]  ; get command code from first byte
0015F   inc edx                     ; move past it
00160   mov eax,dword ptr XLAT_FUNCTABLE[eax*4]   ; find handler
00167   xchg    eax,[esp]           ; put its address on stack
0016A   retn                        ; "return" to it
    V86MMGR Xlat_API    endp
```

Listing 3-14 shows V86MMGR's handler for Xlat_API Exec_Int, which reflects protected mode software interrupts to V86 mode.

Listing 3-14: V86MMGR Code to Handle Xlat_API Exec_Int

```
0016B   push    eax
0016C   movzx   eax,byte ptr [edx]  ; get byte #2 (INT num) from script
0016F   VMMcall Begin_Nest_V86_Exec ; set up for V86 mode
00175   VMMcall Exec_Int            ; interrupt number is in EAX
```

```
0017B   pop eax
0017C   VMMcall End_Nest_Exec
```

The functions Begin Nest V86 Exec, Exec Int, and End Nest Exec are all described in the VMM section of Microsoft's DDK documentation. Begin Nest V86 Exec sets the current virtual machine to V86 mode. Exec Int simulates a specific interrupt in the VM, and End Nest Exec returns everything to normal. We could, of course, now take apart VMM and see how *these* functions, too, are implemented, but while such an exercise could take us a certain shield. However, we will look at VMM a little later to see how it implements some of the DPMI functions.

Note that Windows runs DOS not in real mode but in V86 mode. VMM or any Windows VxD may trap software interrupts, IN or OUT instructions, memory access, and so on from DOS. This means that many actions DOS takes will cause it to pop stack in the Windows VMM.

The simplest possible protected mode INT 21h call in enhanced mode takes the route we've just described. DOSMGR gets the INT 21h call, figures out that it doesn't need to do anything special, and uses a script to call V86MMGR to reflect the INT 21h call to V86 mode. V86MMGR figures out what DOSMGR is asking it to do, and then passes VMM instructions to V86 mode to reissue the INT 21h, and switch back to protected mode.

Yes, all this happens every time a Windows program makes even the simplest INT 21h call. Not that we glossed over many details, such as how the PM callback actually makes the transition to my 16-bit protected mode at Ring 3 to my 32-bit protected mode at Ring 0, but I'm sure you get the idea.

You might think that INT 21 calls for a protected mode client would be very slow. However, the DDK debug version of WDEB386.EXE includes a DOSMGR debug command, "Display DOS time profile", to log the number of INT 21h calls I make in a few seconds. I usually see several *thousand* DOS calls. The most popular are INT 21h AH=2Ah Get System Date, INT 21h AH=4Eh Find Next, and INT 21h AL=50h Set PSP, at a rate of about one per second.

Windows does this so much because it has to keep track of which task is currently active. Windows has an associated PSP value that it keeps up to date every time INT 21h AH=50h Set PSP is executed to switch to a given task. (That is called *reflection*; see page 340 of my second book for details.) This gets off making the Set PSP call the task has made since DOS can't tell when a context switch happens preemptively. Given the architecture, I suppose, because DOS doesn't need PSP values to work with the Windows PSP's, it doesn't bother to keep them up to date. Instead, it intercepts all the accesses to the PSP values and fakes it. For example, INT 21h real mode Set PSP

```
MOV AH,50h
MOV BX,segment
INT 21h
```

actually DOES set PSP, so it's a good example of something that appears to need special handling from DOSMGR. INT 21h AH=50h expects a PSP address in BX, for protected mode, of course. That makes sense, but then the protected mode selector for the PSP. DOSMGR passes the INT 21h to V86 mode, and because DOS, of course, can't handle protected mode PSP's, it must first convert the PSP in BX from a protected mode segment address to a VMM SelectorMapFlat function.

As another example of the care that DOSMGR must provide, special handling is required to consider INT 21h AH=25h Set Interrupt Vector. When called in protected mode, this function not only sets a protected mode interrupt vector, but it also sets a *real mode* vector in DOS memory. V86 mode, instead, DOSMGR must handle the real mode vector by translating it into a call to the VMM Set PM Int Vector function, much the same function that DOSMGR used back in Listing 3-12 to install its own INT 21h protected mode callback. If you actually want to install a real mode interrupt handler from protected mode, you must instead do so in real mode, by hand, for example, using the DPMI Simulate Real Mode Interrupt, which we will discuss later.

Likewise, INT 21h AH=48h Allocate Memory Block, should, in protected mode, allocate extended memory and return protected mode selectors. It wouldn't make sense, in a protected mode version of this function, to allocate conventional memory and return real mode paragraph address so again DOSMGR can't call down to V86 mode. Instead, DOSMGR traps INT 21h AH=48h, executing VMM functions such as PageModify, Allocate LDT Selector, and SetDescriptor to create the

...t INT 21h calls to "V86 land" without calling down to V86 mode were taken to its logical conclusion Windows wouldn't need DOS at all This is what Chicago provides via VxDs such as VFAT 386

How DOSMGR Handles Undocumented DOS Calls

So now does DOSMGR handle undocumented DOS functions We already saw what it does with Set PSP calls but this call was heavily documented in DOS 5 0 so it's no longer a good example Let's return to undocumented function 52h As we all know by heart this function takes no parameters and returns a far pointer to SysVars in ES BX We've seen that Windows somehow transparently makes this work in protected mode since calling INT 21h AH=52h in protected mode gets back a valid protected mode pointer to SysVars Well it's not transparency sort of works since SysVars itself contains real mode segments but DOSMGR is doing the best that is humanly possible DOSMGR can't very well modify SysVars to make it contain protected mode pointers since this would immediately crash DOS

How does DOSMGR give us the illusion of a protected mode DOS that even supports function 52h The DOSMGR script that handles function 52h looks like this

```
Xlat_API_Return_Ptr ES, BX
Xlat_API_Exec_Int 21h
```

DOSMGR also uses this same exact macro to handle the newly documented INT 21h AH=34h (Get INDOS Flag address) which also takes no parameters and returns a far pointer in ES BX You can see how straightforward the INT 21h functions into categories and using the V86MMGR XLAT API facility make it a bit easier to implement a DOS extender

Xlat_API_Return_Ptr's explained in the DDK Its job is to take a real mode pointer in the specified register (here ES BX) and turn it into a protected mode pointer The DDK notes that, although this macro is placed before the Xlat_API_Exec_Int macro in an XLAT script V86MMGR actually creates the protected mode address after servicing the interrupt Showing how V86MMGR implements Xlat_API_Return_Ptr would take us too far off the subject even for this book so we'll simply note that it's similar to the code at the start of the Xlat_API_Exec_Int 21h and then fiddles with the V86 client register structure the Xlat_API_Return_Ptr macro returns ES and BX into Client_ES and Client_BX For its software the VMM Map_Lin_To_VM_Addr function documented in the DDK does the actual real to protected mode pointer conversion

This is certainly important and is a neat example of why it is sometimes helpful to know such low level implementation details The DDK for instance for Xlat_API_Return_Ptr says "For 16 bit protected mode apps this macro converts a LDT selector to an appropriate selector does not already exist" What it doesn't discuss is how these selectors ever get freed Once you know that Xlat_API_Return_Ptr is implemented using Map_Lin_To_VM_Addr you can turn to the DDK documentation for that function and see that it's part is to say that "A virtual device must *never* free a selector that it received as a service for this reason this service should be used sparingly"

This is odd but it actually makes a lot of sense In the case of providing a protected mode interface via Xlat_API_Exec_Int how would DOSMGR know when we were done using SysVars and thus the protected mode pointer to it created with Xlat_API_Return_Ptr and thus with Map_Lin_To_VM_Addr could be freed There is no way to know which is an inherent problem with transparency But there remains a danger that this service could consume selectors of which only 8 192 are available That would never be noticed until the DOS box was thrown away perhaps by a user who had started monitoring Word for Windows' Map_Lin_To_VM_Addr must avoid this danger by keeping a list of selectors it has created It tries to fulfill a request by returning some previously allocated selector, rather than allocating a new one

DOSMGR uses the same Xlat_API_Return_Ptr macro to handle the recently documented INT 21h functions 1Fh Get Default DPB and 32h Get DPB and also to handle functions 1Bh Get Default Drive Data and 1Ch Get Drive Data Because V86MMGR doesn't know the size of the returned

data structures which calling Map Lin To VM Addr V86MMGR always automatically gives the selector a limit of 10FFF 64K. Again these selectors stick around until the VM is shut down.

All this sounds a lot like the DPMI Segment to Descriptor function INT 31h AX 2. See documentation for which warns: Descriptors created this way should never be modified or freed. For this reason, the function is only to be used sparingly. The reason this sounds so familiar is that VMM implements the DPMI call using Map Lin To VM Addr. In fact, since the DPMI function provides a very easy way to turn real mode addresses into protected mode addresses, and since this function is abused and overused. Later in this chapter, when we need to convert real mode addresses to protected mode, we will use a better technique.

Where were we? Right, we were trying to see how DOSMGR handles reflected INT 21h function 52h. The use of V86MMGR makes it not obvious at a level of abstraction. If we step over that and show just the underlying VMM function calls, the protected mode part of our thunk function would look like the code shown in Listing 3-15. Of course, this same code would work just as well for any other function, such as INT 21h AH 34h that also needs an Xlat API Return DS BX and an Xlat API Exec for 21h. Similar code appears later in this chapter in the UNIDOSMGR.ASM source code for a VxD that transparently supports INT 21h AX 5300h in protected mode.

Listing 3-15: Direct implementation for INT 21h Functions 34h and 52h

```
VMMcall Simulate_Iret
VMMcall Begin_Nest_V86_Exec
mov     eax, 21h
VMMcall Exec_Int                ; reflect INT 21h to V86 mode
VMMcall Resume_Exec             ; do it now!
movzx   eax, [ebp.Client_ES]    ; get V86 ES inside nest
VMMcall End_Nest_Exec
shl     eax, 4                  ; make linear address
mov     ecx, 0FFFFh             ; 64k segment
VMMcall Map_Lin_To_VM_Addr      ; create permanent selector
mov     [ebp.C_vent_ES], ax     ; return selector to caller in DS
```

We know at this point how to get into real mode, but we're still in protected mode. Listing 3-15 shows exactly how. We also know that function 5300h doesn't work properly, but we don't know why. Now is the time to find out. The DOSMGR code for INT 21h AX 5300h looks like DOSMGR has a separate code for handling this function. Now, we don't have the INT 21h AH 52h subfunction, so let's see what's executed. For example, the documented Set Extended Error function AX 5D0Ah is much cleaner. You have to either DS:DX or DS:SI is carried by the official exception to this rule is *MS-DOS 7's undocumented Rename* call, but DOS 7 isn't talk to Windows.

```
Xlat_API_Fixed_Len DS, DX, 16h
Xlat_API_Exec_Int 21h
```

The function 5D0A code also contains a handler for AX=5300h. Our SDA. Here it is:

```
Xlat_API_Exec_Int 21h
```

That's it. Because this function is undocumented and simple, function 52h rather obscure DOSMGR does nothing to it other than reflect the INT 21h down to V86 mode. What this means is that on returning from executing INT 21h AX 5300h in protected mode, our segment registers will be *inchanged*. In other words, the function leaves in AX random garbage. It returns the correct offset for the SDA and the segment in DS will be whatever it was before the call. Because of this, CURRDRIVE and other functions in protected mode were looking at some offset in their own data segments!

What have we learned here? First, there should be no mystery about how INT 21h is supported in protected mode. The DOS extender in this case DOSMGR receives INT 21h calls in V86 mode. Many other DOS extenders switch into genuine real mode and convert pointers between

[illegible] mode and protected mode. Sometimes (for example, with file I/O or directory calls) this requires copying [illegible] to and from a conventional-memory transfer buffer.

The [illegible] point is to make the illusion of protected-mode DOS as transparent as possible for the [illegible] DOS [illegible] and [illegible] ones like Function 52h. But there are limits to transparency. [illegible] Windows supports Function 52h. Calling this function in protected mode [illegible] protected mode pointer to SysVars, but SysVars itself (if necessary) still con[illegible] pointers. [illegible] the protected mode support for some documented DOS functions such as IOCTL has similar limitations.

Another limitation of transparency is that the DOS extender has no idea exactly how a program that calls a DOS function is going to use the returned data. This is the problem with any of the DOS [illegible] which return pointers to data and which DOSMGR uses [illegible] DOSMGR [illegible] the protected mode selector descriptor for the returned pointer.

[illegible] tries to do the right thing in protected mode. If MS-DOS were a [illegible] operating system, how would function X behave? But it is not always clear [illegible] makes sense for function 25h in protected mode to install a [illegible] protected mode program still wants to install a real [illegible] the number of functions that [illegible] reasonably be considered [illegible] DOS [illegible]. Many vendors besides Microsoft use INT 21h [illegible] Chapter 1, there are a vast number of functions such as MSCDEX [illegible] INT [illegible] DOSMGR or any other DOS extender could possibly hope to support every one of these functions [illegible] make them work transparently in protected mode.

Do Your Own XLAT

[illegible] DOSMGR [illegible] DOS extender supports or doesn't support a particular DOS function [illegible] mode, or whether it supports or doesn't support a function in the way that would be [illegible]. You can provide your own [illegible] support [illegible] protected mode [illegible] Windows program [illegible] V86 mode [illegible] as DOSMGR would do for supported [illegible] pointers between protected mode and real [illegible] DOSMGR [illegible] DOSMGR, which can't free returned pointers [illegible] whatever the DOS extender [illegible].

[illegible] DOSMGR [illegible] V86MMGR [illegible] services provided by VMM. The key VMM [illegible] Next V86 Exec [illegible] VMM [illegible] these functions [illegible] because [illegible] on top of these VMM functions [illegible] DPMI. When DOSMGR does transparently [illegible] DPMI. In Enhanced mode, DPMI [illegible] DOS applications use some of the functionality of VMM [illegible] VMM [illegible] implementation of the DPMI specification, though it is the [illegible] compatible.

[illegible] DPMI does not supply the necessary functionality, you can also write a VxD [illegible] DOSMGR 386 example at the end of this chapter.

DPMI Programming

Because DOS extenders [illegible] DOS function in protected mode, protected mode programs need [illegible] software interrupts. This requires switching into real or V86 mode, [illegible] and switching back into protected mode. DPMI provides functions for low-level mode switching (INT 31h AX=0305h and 0306h), but fortunately

DPMI also provides a higher level function, Simulate Real Mode Interrupt (INT 31h AX=0300h) which takes care of the low level mode switching for you. We use this function extensively in the remainder of this chapter.

For those occasions when you need to call a real mode function with a real mode address, DPMI also provides two Call Real Mode Procedure functions (INT 31h AX=0301h and 0302h). All of these functions are documented in the DPMI specification available free of charge from Intel. Ray Duncan's *Extending DOS* and Al Williams' *DOS and Windows Protected Mode* also discuss DPMI.

While we're few people use Windows 3.0 anymore, and even fewer use Windows 3.0 Standard mode, we probably ought to note that INT 31h functions 0300h (0301h and 0302h) are not supported in Windows 3.0 Standard mode. According to a Microsoft article (Q72858, "DOS4GW Functions Not Reentrant or Not Valid in Windows Standard Mode"), this was fixed in the Windows 3.0 upgrade.

INT 31h AX=0300h is slightly confusing because you use this software interrupt to generate, actually simulate, you'll see what this means below) a real mode (or V86 mode) software interrupt such as INT 21h AH=52h or AX=5D06h that you are actually interested in. You use this software interrupt to simulate another.

But simulating real mode interrupts is not half the puzzle. It is important to note that using INT 31h AX=0300h to call INT 21h AX=52h or AX=5D06h in real or V86 mode sets up *real mode pointers*. The fact that you are calling the real mode software interrupt using DPMI does not change this. Thus protected mode programs also need to translate these real mode pointers into the protected mode address space, that is, to convert real mode pointers to protected mode pointers. When we're done, we'll have protected mode pointers to data structures in conventional memory. Sometimes, as with SysVars, these structures will contain additional real mode pointers which also must be mapped before a protected mode program can use them.

How are real mode pointers translated to protected mode? We've already hinted at what goes on behind the scenes. DOSMGR uses Get XMS Relocation Pointer, which returns Map Linear Address to XMS Address, to create permanent selectors. This corresponds exactly to the DPMI Segment to Descriptor function (INT 31h AX=2). What we needed was some way to get back which Windows kernel mode segments were set up by Map Linear Address to XMS Address when it returned selectors that we could use in our programs. We need a different technique so that we can free these (Windows won't free them for us). There are only eight bytes in each descriptor table entry, so it would be easy to search all 8,192 descriptors and create selectors because descriptor tables are limited to 64K. I wouldn't recommend this for reasons we won't get into here. There are only 4,096 available descriptors. I wrote a special routine for freeing mapped real mode pointers which we'll look at with the essential Windows code. Windows will free these for you when your program terminates.

Actually, our solution is not to allocate new protected mode pointers in the first place. Windows preallocates several selectors to popular memory locations. These selectors are available for use by Windows programs and drivers. These predefined selectors with base addresses such as 0000h, 0040h and 1000h are described in Chapter 5 of *Undocumented Windows*. Apparently, this is a "flavor" of the Rational Systems DOS extender used by Lotus 1-2-3 Release 3. Lotus accesses selector 40h which is a "potential" selector for this selector's DPL contains its base address for the BIOS data area at 400h. As Matt Pietrek shows in Chapter 1 of his *Windows Internals*, when the Windows kernel initializes, it creates these selectors using INT 31h AX=0002 (Create Alias). These predefined selectors only cover a portion of the real mode address space. Also, they are only available to Windows programs. Protected mode DOS programs can't get at them.

But it's silly to worry too much about these predefined selectors because we can easily create our own protected mode selectors that map real mode addresses. This requires three DPMI functions. Allocate LDT Descriptors (INT 31h AX=0), Set Segment Base Address (INT 31h AX=7), and Set Segment Limit (INT 31h AX=8). As shown below, you allocate a descriptor, set its base address to correspond to the real mode address. You should set the limit to 0FFFFh because a

DOS. In most cases you're interested in rather than blindly make everything 64K as DOSMGR has no [illegible] and you have no way of knowing which others your program will want to use. Setting a small [illegible] saves the size of the structure, and using helps catch all by one errors [illegible] Rather than use DPMI Windows programs can use three Windows API functions AllocSelector, SetSelectorBase, and SetSelectorLimit. The last two functions were at one point [illegible] see *Undocumented Windows* Chapter 5 examines them in detail. Having created the protected mode selector you can then turn it into a usable far pointer with a macro such as MK_FP() (Borland C++ DOS.H) or MAKEP() (WINDOWS.H).

[illegible] we wanted to be able to free one of these mapped protected mode selectors when we [illegible] INT 31h AX=1 Free LDT Descriptor provides this ability (the equivalent Windows API function is FreeSelector).

In ASTDRIV.C CURRDRIV and NEWVEK programs, pretty-print various addresses returned from INT [illegible] and 5300h. The pointers that our protected mode programs see have type [illegible] protected mode addresses created using the DPMI or Windows API functions and must be [illegible] to access portions of these assumed far pointers. In selector whose base address we set to [illegible] mode addresses we're interested in. Offset 0. The base value itself is more or less meaningless [illegible] descriptor table. Printing out these protected mode addresses does will [illegible] We need some way to convert one of these protected mode addresses to get back to real [illegible] to create the real mode address we actually want to display. There's [illegible] DPMI Get Segment Base Address function INT 31h AX=6 or [illegible] Windows API function GetSelectorBase. Of course, only base addresses less than [illegible] DOS-based have real mode equivalents.

[illegible] how can [illegible] DOS functions expect us to pass their buffers which they will fill [illegible] For example, INT 21h AH=3Fh (Read File or Device) wants the way to call the equivalent function from protected mode, we must specify the real mode buffer, but that is not enough. The [illegible] expects INT 21h AH=3Fh DS:DX to be a *real mode* address. This is not to means that the address [illegible] a conventional memory below the megabyte or otherwise how could DOS access it? Yet [illegible] to translate the conventional memory buffer with a protected mode pointer.

A [illegible] called the XMSMGR memory manager such a transfer buffer, which DOSMGR accesses [illegible] support all the disk and file I/O and directory calls. We can allocate our own [illegible] using the DPMI Allocate DOS Memory Block function INT 31h AX=0100h. [illegible] the call mode segment:0 paragraph address of a conventional memory block [illegible] protected mode selector. Programs can read and write to the real buffer [illegible] mode selector, but then pass the real mode paragraph address to DOS INT 21h [illegible] DOS Memory Block frees these buffers. The corresponding Windows API functions are GlobalDOSAlloc() and GlobalDOSFree().

[illegible] DOS from protected mode Windows, you need the following [illegible]

- Allocate LDT Descriptor (AX=0000) or AllocSelector
- Free LDT Descriptor (AX=0001) or FreeSelector()
- Get Segment Base Address (AX=0006) or GetSelectorBase
- Set Segment Base Address (AX=0007) or SetSelectorBase
- Set Segment Limit (AX=0008) or SetSelectorLimit()
- Allocate DOS Memory Block (AX=0100) or GlobalDOSAlloc()
- Free DOS Memory Block (AX=0101) or GlobalDOSFree()
- Simulate Real Mode Interrupt (AX=0300) (no Windows API equivalent)

Now these functions have been discussed in many other places. A number of good articles describe how to use DPMI to access real mode DOS from protected mode Windows, for those times

when the Windows DOS extender doesn't do its work for you. It may seem that we could have documented these eight functions at the beginning of this chapter and been done with it without looking at how DOSMGR is implemented or how Windows programs and protected mode DOS applications. DPMI clients and servers. But without specifying so much trust in looking at what happens when you *don't* use these DPMI functions. However, many times programmers use these DPMI functions in a cookbook fashion without understanding what they actually do or why you use one of these and not another. For example, we've often seen programmers try to use INT 31h AX=0 or GetSelectorBase to call the DOS Truename function from protected mode and waste large amounts of time because it doesn't work. In the long run, it pays to understand what you are doing.

Hiding DPMI

Actually, though having taken so long just to get to the point where most treatments of DPMI start, we're now going to spend very little time looking at these eight DPMI functions. Instead we're going to hide them beneath a higher level, easier to use interface.

For example, to map a real mode address we usually have to worry about combining three different DPMI functions. We're going to hide this complexity by creating a function with a C++ like function call that takes a real mode pointer and the number of bytes you will want to look at from protected mode. It returns an equivalent protected mode pointer. When you are done using the protected mode pointer, you can free it with free_mapped_real:

```
void far *prot_ptr = map_real(real_ptr, number_of_bytes);
// use prot_ptr
free_mapped_real(prot_ptr);
```

Let's continue to hide DPMI. Using one interrupt (INT 31h AX=0300h) to generate another such as INT 21h AH=52h is confusing. But calling a function to get a pointer to the DOS SysVars is something all DOS programmers used to do this way with functions such as int86x (see Chapter 2). We're going to implement real_int86x function that works just like int86x, so that generates a real mode software interrupt from protected mode. We can use this function together with map_real to accomplish most of what we need. For example:

```
union REGS r;
struct SREGS s;
void far *real_sysvars;
void far *prot_sysvars;
memset(&s, 0, sizeof(s));
r.h.ah = 0x52;
real_int86x(0x21, &r, &r, &s);
real_sysvars = MK_FP(s.es, r.x.bx);
prot_sysvars = map_real(real_sysvars, number_of_bytes);
// access SysVars via prot_sysvars
free_mapped_real(prot_sysvars);
```

These functions, real_int86x and map_real, form the core of a library of routines (PROT.C and PROT.H, see Listings 3-16 and 3-17) for protected mode programming with Windows or other DPMI server. In a Windows program, PROT.C uses Windows API functions such as AllocSelector and SetSelectorBase. In a DOS based DPMI program, PROT.H maps these to PROT.C functions such as dpmi_alloc_selector and dpmi_set_selector_base. What PROT.C wrappers for the appropriate DPMI INT 31h calls.

Listing 3-16: PROT.C

```
/*
PROT.C
Routines for protected mode programming with Windows and DPMI
Andrew Schulman, February 1993
from "Undocumented DOS", 2nd edition (Addison-Wesley, 1993)
```

```
(Changed version of PROTMODE, from MSJ, Oct  1992, Dec. 1992)
Requires 286+ instruction set (e.g., bcc -2 or cl -G2)
*/
#include <stdlib.h>
#include <string.h>
#include <dos.h>
#ifndef DPMI_APP
#include  windows.h
#endif
#include "prot.h"
/*************************************************************************/
static WORD mapped = 0,      // to ensure don't have selector leak
WORD get_mapped(void)   { return mapped; }
/*************************************************************************/
static DWORD base = 0;       // for data in other VMs
void set_base(DWORD b)  { base = b; }
DWORD get_base(void)    { return base, }
/*************************************************************************/
void far *map_linear(DWORD lin_addr, DWORD num_bytes)
{
    WORD sel,

    /* allocate a selector similar to our current DS
       (i.e., a data selector) */
    _asm mov sel, ds
    if ((sel = AllocSelector(sel)) == 0)
        return (void far *) 0,

    /* set the base and limit of the new selector; variable "base"
       allows access to data in other VMs */
    SetSelectorBase(sel, base + lin_addr);
    SetSelectorLimit(sel, num_bytes - 1);

    mapped++,

    /* turn into a far pointer */
    return MK_FP(sel, 0);
}
void free_mapped_linear(void far *fp)
{
    FreeSelector(FP_SEG(fp)),
    mapped--;
}
void far *map_real(void far *fp, DWORD size)
{
    return map_linear(MK_LIN(fp), size);
}
/*************************************************************************/
/* Performs a real mode interrupt from protected mode */
BOOL dpmi_rmode_intr(WORD intno, WORD flags,
    WORD copywords, RMODE_CALL far *rmode_call)
{
    // ignore flags
    _asm  push di
    _asm  push bx
    _asm  push cx
    _asm  mov ax, 0300h        // simulate real mode interrupt
     asm  mov bx, intno        // interrupt number, flags
    _asm  mov cx, copywords    // words to copy from pmode to rmode stack
     asm  les di, rmode_call   // ES:DI = address of rmode call struct
```

```
    _asm  int 31h              // call DPMI
    _asm  jc error
    _asm  mov ax, 1            // return TRUE
    _asm  jmp short done
error:
    _asm mov ax, 0             // return FALSE
done:
    _asm pop cx
    _asm pop bx
    _asm pop di
}
/*****************************************************************************/
int real_int86x(int intno, union REGS *inregs, union REGS *outregs,
    struct SREGS *sregs)
{
    RMODE_CALL r;
    memset(&r, 0, sizeof(r)); // initialize all fields to zero  important!
    r.edi = inregs->x.di;    r.esi = inregs->x.si;
    r.ebx = inregs->x.bx;    r.edx = inregs->x.dx;
    r.ecx = inregs->x.cx;    r.eax = inregs->x.ax;
    r.flags = inregs->x.cflag;
    r.es = sregs->es;        r.ds = sregs->ds;
    r.cs = sregs->cs;
    // NOTE:  r.ss=r.sp=0 so that DPMI host provides real mode stack!
    if (! dpmi_rmode_intr(intno, 0, 0, &r))
    {
        outregs->x.cflag = 1;   // error: set carry flag!
        return 0;
    }
    sregs->es = r.es;        sregs->cs = r.cs;
    sregs->ss = r.ss;        sregs->ds = r.ds;
    outregs->x.ax = r.eax;   outregs->x.bx = r.ebx;
    outregs->x.cx = r.ecx;   outregs->x.dx = r.edx;
    outregs->x.si = r.esi;   outregs->x.di = r.edi;
    outregs->x.cflag = r.flags & 1; // carry flag
    return outregs->x.ax;
}
int real_int86(int intno, union REGS *inregs, union REGS *outregs)
{
    struct SREGS sregs;
    memset(&sregs, 0, sizeof(sregs));
    return real_int86x(intno, inregs, outregs, &sregs);
}
int real_intdos(union REGS *inregs, union REGS *outregs)
{
    return real_int86(0x21, inregs, outregs);
}
int real_intdosx(union REGS *inregs, union REGS *outregs,
    struct SREGS *sregs)
{
    return real_int86x(0x21, inregs, outregs, sregs);
}
/*****************************************************************************/
WORD lar(WORD wSeg) // load access rights
{
    _asm lar ax, wSeg
    _asm jnz error
    _asm shr ax, 8
    _asm jmp short done; // value in AX
error:
    return 0;            // can't be a valid AR
done:;
}
```

```
void far *lin_to_real(DWORD lin_addr)
{
    if (lin_addr > 0x10FFEFL)   /* allow HMA pointers up to FFFF:FFFF */
        return NULL;            /* not accessible in real mode */
    else
    {
        WORD seg, ofs;
        seg = (lin_addr > 0x100000L) * 0xFFFF   (lin_addr >> 4);
        ofs = lin_addr - ((DWORD) seg << 4L);
        return MK_FP(seg, ofs);
    }
}

void far *get_real_addr(void far *fp)   /* prot to real */
{
    DWORD base;
    if (lar(FP_SEG(fp)) == 0)
        return NULL;    /* not a valid pointer */
    base = GetSelectorBase(FP_SEG(fp));
    return (lin_to_real(base + FP_OFF(fp));
}
/*************************************************************************/
BOOL alloc_real_seg(DWORD bytes, WORD *ppara, WORD *psel)
{
    DWORD dw = GlobalDosAlloc(bytes);
    if (! dw) return 0;
    *ppara = HIWORD(dw);
    *psel  = LOWORD(dw);
    return 1;
}
BOOL free_real_seg(WORD sel)
{
    return (GlobalDosFree(sel) == 0);
}
/*************************************************************************/
#ifdef DPMI_APP
WORD dpmi_alloc_selector(void)
{
     _asm xor ax, ax
    _asm mov cx, 1
    _asm int 31h
    _asm jc error
    _asm jmp short ok
error:
    return 0;
ok:
    // return value in AX
}
WORD dpmi_free_selector(WORD sel)
{
     _asm mov ax, 1
    _asm mov bx, sel
    _asm int 31h
    _asm jc error
    _asm jmp short ok
error:
    return sel; // act like the Windows function
ok:
    return 0;
}
WORD dpmi_set_selector_base(WORD sel, DWORD base)
{
    _asm mov ax, 7
```

```
    _asm mov bx, sel
    _asm mov cx, word ptr base+2
    _asm mov dx, word ptr base
    _asm int 31h
    _asm jc error
    _asm jmp short ok
error:
    return sel,
ok:
    return 0;
}
WORD dpmi_set_selector_limit(WORD sel, DWORD limit)
{
    _asm mov ax, 8
    _asm mov bx, sel
    _asm mov cx, word ptr limit+2
    _asm mov dx, word ptr limit
    _asm int 31h
    _asm jc error
    _asm jmp short ok
error:
    return sel,
ok:
    return 0;
}
DWORD dpmi_get_selector_base(WORD sel)
{
    _asm mov ax, 6
    _asm mov bx, sel
    _asm int 31h
    _asm jc error
    // return CX DX in DX,AX
    _asm mov ax, dx
    _asm mov dx, cx
    _asm jmp short done
error:
    return 0,   // problem: instinguishable from 1-byte segment!
done:;
}

/* C interface to LSL (Load Segment Limit) instruction */
#pragma warn -rvl
WORD lsl(WORD sel)
{
    if (! sel) return 0,   /* workaround 386 bug: Hummel, p.471 */
    _asm lsl ax, sel
}

DWORD dpmi_get_selector_limit(WORD sel)
{
    // no DPMI function, use LSL, should use 32-bit LSL though!
    return (DWORD) lsl(sel);
}

DWORD dpmi_dos_alloc(DWORD bytes)
{
    DWORD retval,
    WORD paras = (bytes >> 4) + 1;
    _asm mov ax, 0100h
    _asm mov bx, paras
    _asm int 31h
    _asm jc error
    _asm mov word ptr retval, ax
    _asm mov word ptr retval+2, dx
    return retval;
error:
```

```
    return DL;
}

WORD dpmi_dos_free(WORD sel)
{
     _asm mov ax, 0101h
     _asm mov dx, sel
     _asm int 31h
     _asm jc error
     return 0;
error:
     return sel;
}
#endif
```

Listing 3-17: PROT.H

```
/*
PROT.H -- see PROT.C
Andrew Schulman, February 1993
from "Undocumented DOS", 2nd edition (Addison-Wesley, 1993)
*/

#ifndef _PROT_H
#define _PROT_H

#ifdef DPMI_APP
typedef int BOOL;
typedef unsigned char BYTE;
typedef unsigned short WORD;
typedef unsigned long DWORD;
#define LOWORD(dw)      ((WORD)(dw))
#define HIWORD(dw)      ((WORD)((DWORD)(dw) >> 16))
#else
#include "windows.h"
#endif

void far *map_real(void far *fp, DWORD size);
void set_base(DWORD b);
DWORD get_base(void);
void far *map_linear(DWORD lin_addr, DWORD num_bytes);
void free_mapped_linear(void far *fp);
WORD get_mapped(void);
void far *get_real_addr(void far *fp);
BOOL alloc_real_seg(DWORD bytes, WORD *ppara, WORD *psel);
BOOL free_real_seg(WORD sel);

#define free_mapped_real(x)     free_mapped_linear(x)

#ifndef MK_FP
#define MK_FP(seg, ofs) \
    ((void far *) (((unsigned long) (seg) << 16) | (ofs)))
#endif

#define MK_LIN(fp) \
    (((DWORD) FP_SEG(fp) << 4) + FP_OFF(fp))

typedef struct {
    unsigned long edi, esi, ebp, reserved, ebx, edx, ecx, eax;
    unsigned flags, es, ds, fs, gs, ip, cs, sp, ss;
    } RMODE_CALL;

BOOL dpmi_rmode_intr(WORD intno, WORD flags,
    WORD copywords, RMODE_CALL far *rmode_call);

int real_int86x(int intno, union REGS *inregs, union REGS *outregs,
    struct SREGS *sregs);
int real_int86(int intno, union REGS *inregs, union REGS *outregs);
int real_intdos(union REGS *inregs, union REGS *outregs);
int real_intdosx(union REGS *inregs, union REGS *outregs,
```

```
    struct SREGS *sregs);
// to be defined by application;
// if DPMI_APP, app's fail() must call _dos_exit'
extern void fail(const char *s, ...);

#ifdef DPMI_APP
#define AllocSelector(x)        dpmi_alloc_selector()
#define FreeSelector(x)         dpmi_free_selector(x)
#define SetSelectorBase(x,y)    dpmi_set_selector_base((x), (y))
#define SetSelectorLimit(x,y)   dpmi_set_selector_limit((x), (y))
#define GetSelectorBase(x)      dpmi_get_selector_base(x)
#define GetSelectorLimit(x)     dpmi_get_selector_limit(x)
#define GlobalDosAlloc(x)       dpmi_dos_alloc(x)
#define GlobalDosFree(x)        dpmi_dos_free(x)

WORD dpmi_alloc_selector(void);
WORD dpmi_free_selector(WORD sel),
WORD dpmi_set_selector_base(WORD sel, DWORD base);
WORD dpmi_set_selector_limit(WORD sel, DWORD limit),
DWORD dpmi_get_selector_base(WORD sel),
DWORD dpmi_get_selector_limit(WORD sel),
DWORD dpmi_dos_alloc(DWORD bytes),
WORD dpmi_dos_free(WORD sel),
#endif
#endif
```

In addition to real_int86x() there are the real_int86() real_intdos() and real_intdosx() functions. All of these functions in turn call dpmi_rmode_int() and do little more than reformat the union REGS and struct SREGS structures. DOSX.H (see Chapter 2) and DPMI specify RMODE_CALL structure. The dpmi_rmode_int() function also in PROT.C provides a wrapper for the DPMI Simulate Real Mode Interrupt function (INT 31h AX=0300h). Of course, you can call dpmi_rmode_int() directly if you prefer this to real_int86x().

About the only item worthy of note is that real_int86x() zeros out all fields in the DPMI RMODE_CALL structure and in particular forces the SS:SP fields in the structure to zero. This tells the DPMI host to provide a real mode stack rather than expecting us to provide one. Note also that the segment register fields in the structure should contain values that are meaningful in real mode. It is not useful for a protected mode program to initialize these fields with the values of the actual segment registers from segread(), for example, because these are protected mode values which real mode would interpret incorrectly.

The map_real() function is more interesting. As noted earlier, this function hides the work of three DPMI functions. Actually, map_linear() is the function that does all the work; map_real() consists of just a single call to map_linear() using the MK_LIN() macro from PROT.H. Employing the familiar ruse of real mode addressing, linear = seg * 16l + offset. MK_LIN() converts a segment:offset real mode address to a so-called *linear address*. A linear address is an index into the protected mode address space. If paging is enabled, as is usually the case in Windows Enhanced mode, then it is not necessarily a physical address. This is an important issue, but one that need not concern us right now.

The map_linear() function calls INT 31h AX=0 (or AllocSelector()) to allocate a new protected mode selector. The function also calls INT 31h AX=7 (or SetSelectorBase()) to set the new selector's base address to the linear address parameter. Optionally, map_linear() can add in a base value we'll use this later (see Listing 3-23) for example, for accessing data in other virtual machines. By default, the base is zero, so map_linear() creates selectors that map data in the current VM. The function next calls INT 31h AX=8 (or SetSelectorLimit()) to set the new selector's limit to the size that was requested, actually to one less than the size requested since the limit is not the size of the segment but its last valid byte offset (a one byte segment has a limit of zero, for example). Finally, the function uses the MK_FP() macro to turn this selector into a far pointer.

The resulting far pointer is just as usable in protected mode as regular far pointers are in real mode. For example, to access four bytes at linear address 12345h in real mode you could just create a pointer with a value of 1234:0005 or 1230:0045 or any number of other segment:offset combinations. To access this from protected mode, you need to call map_real() with 0x12345L. This returns a segment:offset far pointer whose offset is zero and whose segment is some essentially meaningless value that indexes into the descriptor table. But the segment's underlying base address will be 12345h. From then on, to read or write to 12345h, all we really care about is getting the segment and offset that we can actually use. Whatever the pointer's segment and offset have. If the pointer ends up referring to address 12345h, it could be 0000:0000 for all we care. Think of map_real() as creating pointers to look good on machines for real mode pointers.

Finally, there's a function that decrements a count of mapped selectors. free_mapped_linear() releases the selector you specify, the counter will get mapped. Also, Selector_ready() tells you if a selector was previously allocated but is *not* automatically deallocated when your program exits. It's up to you to free up any selectors you allocate. By checking that get_mapped() returns zero just before your program terminates, you can ensure that you have been a good citizen.

Fixing SFTWALK

We've used many of the 1850+ real mode interrupt routines to redevelop earlier applications. It would be redundant to do that here. Instead, we'll just redo SFTWALK.C from Listing 3-5 and add INT86() and DRIVE_INFO() versions for the reader. Listing 3-18 shows the new version of SFTWALK.C. This program can be linked with either DPMI_APP1.LIB containing the DOS_MISC.OBJ or PROT.OBJ (which I'll show later). Listings 3-6, 3-7, and 3-16. In addition to the DPMI version, SFTWALK now also includes code for making a Windows version. The Windows version is built by linking with WIN_APP1.LIB which contains the PRINTF.OBJ (Listing 3-17) and PROT.OBJ routines. WIN_APP1.LIB, of course, does *not* include the DPMISH.OBJ module.

Listing 3-18: SFTWALK.C (Fixed for Protected Mode)

```
/*
SFTWALK.C -- Count FILES= by Walking SFTs
Version #2, uses real_intB6xf() and map_real() in PROT.C
Andrew Schulman, March 1993
From  Inside Protected DOS , 2nd edition (Addison-Wesley, 1993)

DPMI program
bcc -c  DDPMI APP  2 dpmish.c prot.c ctrl.c asm
tlib dpmi_app +dpmish.obj +ctrl.c.obj +prot.obj
brc  DDPMI APP  2 sftwalk.c dpmi_app.lib

Windows program
bcc -c -W -2 -DWINDOWS printf.c prot.c
tlib win_app-+printf.obj-+prot.obj
bcc -W -2 -DWINDOWS sftwalk.c win_app.lib
*/

#include <stdlib.h>
#include <string.h>
#include <dos.h>

#ifdef DPMI_APP
#define PROT_MODE
#include "dpmish.h"
#include "prot.h"
#endif

#ifdef WINDOWS
#define PROT_MODE
#include "windows.h"
#include "prot.h"
#include "printf.h"
```

```
#else
#include <stdio.h>
#endif

typedef unsigned char BYTE,
typedef unsigned short WORD,

// moved here (and changed) from SYSVARS.C
BYTE far *get_sysvars(void)
{
#ifdef PROT_MODE
    union REGS r;
    struct SREGS s;
    r.h.ah = 0x52,
    /* do not pass in garbage for seg regs, but don't use
       segread() either! Use memset to initialize to zero  */
    memset(&s, 0, sizeof(s));
    s.es = r.x.bx = 0;
    real_int86x(0x21, &r, &r, &s);
    return (BYTE far *) map_real(MK_FP(s.es, r.x.bx), 0xFFFF),
#else
    _asm xor bx, bx
    _asm mov es, bx
    _asm mov ah, 52h
    _asm int 21h
    _asm mov dx, es
    _asm mov ax, bx
    // return value in DX:AX
#endif
}

typedef struct _sft {
    struct _sft far *next;
    WORD num,
    // other stuff not used here
    } SFT;

int do_sftwalk(void)
{
    BYTE far *sysvars,
    SFT far *sft, far *next,
    WORD num_mapped,
    int files = 0;

    if (! (sysvars = get_sysvars()))
        return 0;
    sft = *((SFT far * far *) &sysvars[4]);
    next = sft;
#ifdef PROT_MODE
    sft = (SFT far *) map_real(sft, sizeof(SFT));
#endif
    while (FP_OFF(sft) != 0xFFFF)
    {
        files += sft->num;
#ifdef PROT_MODE
{
        // print out, using saved real mode address
        // (printing out the protected mode address isn't helpful)
        printf("SFT @ %Fp — %u files\n", next, sft->num),
        next = sft->next;                   // save ptr to next
        free_mapped_real(sft);              // zap old one
        if (FP_OFF(next) == 0xFFFF)         // at end of list
            break,
        sft = (SFT far *) map_real(next, sizeof(SFT));  // map new one
}
#else
```

```
        printf("SFT @ %Fp -- %u files\n", sft, sft->num);
        sft = sft->next;
#endif
    }
    printf("FILES=%d\n", files);

#ifdef PROT_MODE
    free_mapped_real(sysvars);
    if ((num_mapped = get_mapped()) != 0)
        printf("Didn't free all selectors! %u remaining!\n", num_mapped);

    return num_mapped;
#else
    return 0;
#endif


#ifdef DPMI_APP
void fatal(const char *s)    { puts(s); dos_exit(1); }
real_main(int argc, char *argv[]) { return 0; }

main(int argc, char *argv[]) { return do_sftwalk(); }
#else
// Windows program
#ifdef __cplusplus
extern "C" int PASCAL WinMain(HANDLE hInstance, HANDLE hPrevInstance,
    LPSTR lpszCmdLine, int nCmdShow);
#endif

int PASCAL WinMain(HANDLE hInstance, HANDLE hPrevInstance,
    LPSTR lpszCmdLine, int nCmdShow)

    int retval;
    open_display("SFTWALK");
    retval = do_sftwalk();
    show_display();
    return retval;
}
#endif
```

Note that SFTWALK not only calls map_real_far for SysVars but also calls the function for each SFT pointer. The real SFT pointer in SysVars is a real mode pointer, as is each next SFT pointer in the linked list. Writing the real mode version of SFTWALK can follow the list with a simple sft = sft->next; the protected mode version has to go to considerably more trouble. Note that while it would be nice to [illegible] this code would be incorrect because it would consider a selector. We must stick to a call to [illegible] to translate the SFT pointer to the mapped real; however we must first [illegible] real mode. Walking the real mode linked lists from protected mode is a little [illegible] this also means that SFTWALK calls get_mapped before exiting and will [illegible] any outstanding allocated selectors.

When [illegible] SFTWALK now works in protected mode. It doesn't complain, so we are freeing all allocated selectors. And it produces the same output as the real mode version. Actually, that [illegible] pointer that SFTWALK uses would not be helpful, because it is a protected mode value and gives us no indication of where the SFT actually is. In fact, displaying the protected mode SFT pointers always displays the same address over and over because as soon as the program [illegible] it allocates a new one. Usually the program ends up reusing the same selector [illegible] SFTWALK prints out the real mode SFT pointer value *before* converting the pointer to protected mode with map_real. Remember the point made earlier that there's nothing wrong with displaying real mode pointers in protected mode; you just can't dereference them.

SETVALK could instead have used the get real address function from PROTO.C to retrieve the underlying real mode pointer from one of the protected mode pointers. However, the resulting real mode pointer is not necessarily in its most familiar form. Many real mode segment:offset combinations converge on the same linear address, so the real to linear function is not reversible. One linear address can yield many different segment:offset combinations, and the one that get real address generates may not be the same as the one that was fed into map real. They do have the same linear address, of course.

Inside the DPMI Server in VMM

The underlying DPMI or Windows functions used in real in386x and map real are such a well hidden that we can now forget about them and proceed with writing DPMI or Windows programs that use undocumented DOS.

But since we are so dependent on these underlying DPMI functions, it pays to ask what they actually do, and what part of Windows provides them. Who is hooking INT 31h in protected mode and INT 21h in V86 mode, and what do they do when one of these DPMI functions gets called?

In Standard mode, the DPMI server is part of DOSX.EXE, along with the DOS Extender. DOSX is a surprising program in its own right, a general purpose DOS extender and DPMI server not really tied to Windows. But our focus here is on Enhanced mode, since that is what the vast majority of Windows users are running. The Enhanced mode DPMI server is part of VMM, which you may recall is the Virtual Machine Manager upon which all VxDs including DOSMGR are ultimately based. VMM is the first 32 bit component in WIN386.EXE. A discussion of VMM could be the subject of entire books, especially since with Microsoft's forthcoming Chicago this topic will grow in importance. But for now we'll look only at the DPMI server inside VMM. What really goes on when we make a DPMI call in Enhanced mode?

First, VMM hooks INT 21h in both V86 and protected mode. The INT 21h hook is used not only to handle DPMI calls such as Function 1686h, Get CPU Mode, used in dpmi.prg presented in Listing 3.6, and Function 1687h, Obtain Real to Protected Mode Switch Entry Point, used in dpmi.prg in Listing 3.6, but also to handle non-DPMI INT 21h calls. The calls constitute the only API that Windows provides to non-Windows applications. Microsoft documents most of these calls but unfortunately in a very obscure location: Appendix C, "Windows Interrupt 21h Services and Notifications," in the Windows 3.1 DDK *Device Driver Adaptation Guide*.

A number of these functions are just thin layers on top of VMM. For example:

- INT 21h AX 1680h, Release Current VM Time Slice, documented in the *MS DOS Programmer's Reference* as the MS DOS Idle Call, does little more than call the VMM Release Time Slice function.
- INT 21h AX 1681h, Begin Critical Section, calls VMM Begin Critical Section.
- INT 21h AX 1682h, End Critical Section, calls VMM End Critical Section.
- INT 21h AX 1683h, Get Current Virtual Machine ID, extracts the VMID from the VM's control block. (To see the current VM, run the VMWALK.EXE in Listing 3.24, later in this chapter.)
- INT 21h AX 1686h, Get CPU Mode, checks the VMSTAT_PM_EXEC bit in the current VM CB's status field.

VMM makes no distinction between the DPMI and non-DPMI INT 21h calls. From looking at the VMM code, DPMI appears to have started simply as a way for VMM to export some of its functionality to less privileged clients only later did it become a separate specification shaped by vendors outside Microsoft.

We are more interested in the DPMI INT 31h functions. To install a protected mode INT 31h handler, VMM calls Allocate PM Call Back and Set PM Int Vector. The DDK documents all these VMM functions, as does Daniel Norton's book *Writing Windows Device Drivers*. The main INT 31h handler is just a few lines of code, using a jump table to get to handlers for the specific DPMI function groups: AH=0 for LDT management services, AH=1 for DOS memory management services, AH=2 for interrupt management services, AH=3 for translation services, and so on. These handlers in turn invoke other handlers for the specific DPMI functions (AX=0 for Allocate LDT Descriptor, AX=1 for Free LDT Descriptor, and so on).

For example, the DPMI Segment to Descriptor function (INT 31h AX=2) was described earlier as nothing more than a layer on top of the VMM Map Lin To VM Addr function. Here's what the VMM code for this function actually looks like:

```
        DPMI_0002                       ; Segment to Descriptor
0A897       movzx eax, [ebp.Client_BX] ; BX=real mode segment address
0A89B       shl eax,4                   ; EAX=linear address now
0A89E       mov ecx,0FFFFh              ; ECX=limit (make 64k)
0A8A3       VMMcall Map_Lin_to_VM_Addr
0A8A9       jc DPMI_ERROR
0A8AF       mov [ebp.Client_AX],cx      ; return selector to caller in AX
0A8B3       jmp DPMI_OK
```

Unfortunately, the DPMI function we're most interested in, Simulate Real Mode Interrupt (INT 31h AX=0300h), is sufficiently complicated that to show its implementation in full detail would require more space than we have here. We can summarize the function's operation, however, by noting that it makes the following sequence of VMM calls:

```
Push_Client_State
Begin_Nest_V86_Exec
Simulate_Int (or Exec_Int)
Resume_Exec
End_Nest_Exec
Pop_Client_State
```

This looks a lot like what Nlat API Exec does when DOSMGR asks it to reflect INT 21h to V86 mode (Sec. Listing 3.15). In fact these functions are a lot alike. Remember, by using DPMI you are just doing by hand what DOSMGR or another DOS extender does or would do transparently. In essence, the DPMI Simulate Real Mode Interrupt function sets up the VM for V86 mode and tells VMM to simulate a software interrupt. Simulate means that rather than use an actual INT instruction, VMM gets the appropriate interrupt handler's address from the low-level interrupt vector table and shuffles the stack so that when the VM runs in Resume_Exec it returns to this address.

The three DPMI functions used to build map linear and map real to AllocSelector (INT 31h AX=0), SetSelectorBase (INT 31h AX=7), and SetSelectorLimit (INT 31h AX=8) are easier to describe. Once again, it would be tedious to show the actual VMM code. The AllocSelector call is based on the VMM Allocate LDT Selector function documented in the DDK. This call also uses the GetDescriptorDWORDs. The two SetSelectorX calls are built using GetDescriptor and SetDescriptor.

Interestingly, the equivalent Windows API functions are *not* implemented using the DPMI calls. Instead, these functions bang directly on the LDT. *Undocumented Windows* (Chapter 5) shows the code for these two functions. According to Matt Pietrek's *Windows Internals* (Chapter 2), the Windows kernel bypasses DPMI for performance reasons. A version of the Windows KERNEL that purely used DPMI was apparently built at one time, but Microsoft found it to be too slow (and, perhaps, too portable to other operating systems). Of course, the rest of us are still supposed to use DPMI instead of banging directly on descriptor tables.

In any case, the code in *Undocumented Windows* shows for these functions is extremely simple. You could, if you cared to, implement your own SetSelectorX and GetSelectorX functions without using Windows or DPMI, by directly manipulating the LDT. There is no reason to, but it shows that here, at least, there isn't any big mystery about what is happening behind the scenes.

Basically, then, the DPMI functions used to implement map real are just conveniences. The DPMI Simulate Real Mode Interrupt call, however, carries out a lot of such magical tasks that we probably could never carry out on our own.

Back to Windows Programming

Having used map real and real int86x in DPMI programs, we can now return to Windows programming and use these same two functions. In a Windows application, map real uses the Windows API functions rather than the DPMI INT 31h functions; real int86x continues to use the DPMI function, which has no Windows API equivalent. Windows applications can call DPMI directly because, as noted before, Windows applications are just DPMI clients. They are essentially the same as the DOS programs we built with DPMISH, except that someone (the Windows kernel) has already called INT 2Fh AX=1687h and switched into protected mode for them. Yet they have a fancier user interface, they use a different EXE file format, and under Enhanced mode all run together in a single virtual machine called the System VM, rather than in separate DOS boxes. ("and cost a lot more to develop," adds one tech reviewer.)

Okay, so there are a lot of differences between Windows programs and protected mode DOS programs. But once you can profitably view Windows applications as nothing more than fancy-looking DPMI clients, then everything we learned about using DPMI in protected mode DOS programs applies to Windows applications. The real int86x and map real functions can help turn most undocumented DOS interfaces into bona fide Windows applications.

Windows and the SFT

Back in Listing 3-18, SFTWALK was built as a DPMI program using DPMI APP LIB. WIN APP LIB can now help turn SFTWALK into a Windows program, one that doesn't GP fault and that correctly determines the DOS FILES= value, just as the real mode and DPMI versions did. Figure 3-5 shows the Windows version of SFTWALK.

Figure 3-5: SFTWALK as a Windows program

```
SFT @ 0116:00CC -- 5 files
SFT @ 05EB.0000 -- 40 files
SFT @ 23C6.0000 -- 82 files
FILES=127
```

This is certainly a nice contrast to the GP fault message in Figure 3-3, but note that this output is different from that produced by the DPMI APP version or by the real mode version when run outside Windows under plain vanilla DOS. We get three different results from SFTWALK:

	MS-DOS	Windows DOS box	Windows application
SFT #1	0116 00CC (5)	0116 00CC (5)	0116 00CC (5)
SFT #2	05EB 0000 (40)	05EB 0000 (40)	05EB 0000 (40)
SFT #3	none	1295 0004 (10)	23C6 0000 (82)
FILES=	45	55	127

What has happened? The differences shown in the table depend not on the type of application but rather on *where* the application is run. For DOS boxes (VMs other than the System VM), Windows Enhanced mode has a PerVMFiles= setting whose default is 10. DOSMGR adds an extra private SFT to each DOS box. Note that DOSMGR can do this only if the DOS SHARE utility is not loaded. SHARE must be able to enumerate all open files, and it wouldn't be able to if DOS boxes had their

own private SFTs. To the System VM, the Windows kernel tries to add a much larger extra SFT to use as a file handle cache. Chapter 1 discussed this topic in the sections "CON CON CON CON CON" (one user that crazyness) and "IKRN1386 Grows the SFT." SFTWALK lets us see the results of Windows' manipulation of the SFT chain.

When a Windows VM adding its own private SFT, Windows must instance the "next" pointer at the end of the pre-Windows SFT chain. In the examples we've been looking at here, this pointer is stored in the DWORD at 0:[BX]+4000h. Unlike a DOS internal data structure such as the CDS, the extra SFTs are instanced only the link from the global SFT to the private ones (see "Instanced Data Segments in Enhanced Mode Windows," MSKB Q90796, and "Limits on the Number of Open Files," MSKB Q81777). The SFT link instancing code in IOSMGR looks like this:

```
06377   mov eax, SFT PTR                ; end of pre-Windows SFT chain
0637C   mov dword ptr [esi+8],eax       ; esi is inst struct
0637F   mov dword ptr [esi+0Ch],4       ; 4 bytes = SFT ptr link
06386   mov dword ptr [esi+10h],200h   ; instance flag = ALWAYS_Field
0638D   push    0
0638F   push    esi
06390   VMMCall _AddInstanceItem
```

It's not clear why Windows goes to such trouble over the SFT. Modifying SFTWALK to print out the actual file names in each SFT or porting the FILES program from Chapter 8 (Listing 8-19) shows that only a few of the Windows applications you run at the same time use only a small portion of the available SFT entries. The SYSTEM.INI [386Enh] section has a FileSysChange=off setting which defaults to on. Increasing this number appears to have no effect, at least in Windows 3.1 Generally, the SFT entries themselves are the names of only the files used by the most recently opened large application. This cache is supposed to help with Windows dynamic linking; see the IFSHLP.SYSBufferHandle description in Chapter 5 of *Undocumented Windows*.

Walking the Device Chain

In the same way that SFTWALK follows the linked list of SFTs from protected mode Windows, we can write code for a Windows program that walks the DOS device chain. You can build DEV.C (shown in Listing 3-19) with the following command lines for DOS or protected mode Windows. When built for Windows, the program of course uses the real-mode int86x() and intdosx() functions from PROTO.C. However, to reduce the number of #ifdef WINDOWS preprocessor directives, DEV.C employs a number of macros such as MAP_real_TO_PM() and FREE_PM_MAP() which call the appropriate functions under Windows but which do nothing when under DOS. Figure 3-6 shows output from DEV.

Listing 3-19: DEV.C for Windows or DOS

```
/*
DEV.C    display MS DOS device chain -- for Windows
Andrew Schulman, March 1993

Real mode DOS:  bcc dev.c

Windows
bcc -c -2 -DWINDOWS -W prot.c printf.c
tlib win_app +prot.c +printf.c
bcc -2 -DWINDOWS -W dev.c win_app.lib
*/

#include <stdlib.h>
#include <stdio.h>
#include <string.h>
#include <dos.h>
#ifdef WINDOWS
#include <windows.h>
#include "prot.h"
#include "printf.h"
```

```
#endif
#ifdef WINDOWS
char *app = "Walk DOS Device Chain";
#define puts(s)          MessageBox(NULL, s, app, MB_OK)
#endif
// this fail() not suitable for a DPMI_APP (which would
// need to do a _dos_exit()
void fail(const char *s, ... ) { puts(s), exit(1), }
#ifndef MK_FP
#define MK_FP(seg, ofs) \
    ((void far *) (((unsigned long) (seg) << 16)   (ofs)))
#endif
#ifdef WINDOWS
#define MAP(ptr, bytes)     map_real((ptr), (bytes))
#define FREE_MAP(ptr)       free_mapped_linear(ptr)
#define GET_REAL(ptr)       get_real_addr(ptr)
#define YIELD()             yield()
#else
#define MAP(ptr, bytes)     (ptr)
#define FREE_MAP(ptr)       /**/
#define GET_REAL(ptr)       (ptr)
#define YIELD()             /**/
#endif
/* some device attribute bits */
#define CHAR_DEV    (1 << 15)
#define INT29       (1 << 4)
#define IS_CLOCK    (1 << 3)
#define IS_NUL      (1 << 2)
#pragma pack(1)
typedef struct DeviceDriver {
    struct DeviceDriver far *next;
    unsigned attr;
    unsigned strategy,
    unsigned intr;
    union {
        unsigned char name[8],
        unsigned char blk_cnt;
        } u;
    } DeviceDriver,
typedef struct {
    unsigned char misc[8],
    DeviceDriver far *clock,
    DeviceDriver far *con,
    unsigned char misc2[16];
    DeviceDriver nul,   /* not a pointer */
    // ..
    } ListOfLists;  // DOS 3.1+
ListOfLists far *get_doslist(void)
{
    union REGS r;
    struct SREGS s,
    memset(&r, 0, sizeof(r));
    memset(&s, 0, sizeof(s));
    r.x.ax = 0x5200,
#ifdef WINDOWS
    /* If Windows, call undocumented DOS INT 21h function 52h via DPMI
       "Simulate Real Mode Interrupt" call (INT 31h AX=0300h), and return
       the resulting real mode pointer  */
    real_int86x(0x21, &r, &r, &s);
#else
    int86x(0x21, &r, &r, &s),
```

```
#endif
    return (ListOfLists far *) MK_FP(s.es, r.x.bx);
}

#ifdef WINDOWS
#ifdef __cplusplus
extern "C" int PASCAL WinMain(HANDLE hInstance, HANDLE hPrevInstance,
    LPSTR lpszCmdLine, int nCmdShow);
#endif

int PASCAL WinMain(HANDLE hInstance, HANDLE hPrevInstance,
    LPSTR lpszCmdLine, int nCmdShow)
#else
int main(int argc, char *argv[])
#endif
{
    ListOfLists far *doslist;
    DeviceDriver far *dd;
    DeviceDriver far *next;

#ifdef WINDOWS
    if (! (GetWinFlags() & WF_PMODE))
        fail( This program requires Windows Standard or Enhanced mode");

    // could also do protected mode DOS version with DPMI
#endif

    if (! (doslist = get_doslist()))
        fail("INT 21h Function 52h not supported");

#ifdef WINDOWS
    /* get protected mode pointer to DOS internal variable table */
    doslist = (ListOfLists far *) map_real(doslist, sizeof(ListOfLists));

    open_display(app);
#endif

#define PARANOID
#ifdef  PARANOID
    /* This block of code just double-checks that everything is ok */

    /* NUL is part of DOSLIST, not a pointer, so don't need to map */
    if (_fmemcmp(doslist->nul.u.name, "NUL     ", 8) != 0)
        fail("NUL name wrong");
    if (! (doslist->nul.attr & IS_NUL))
        fail("NUL attr wrong");

    /* CON is pointer, so need to map */
    dd = (DeviceDriver far *) MAP(doslist->con, sizeof(DeviceDriver));
    if (_fmemcmp(dd->u.name, "CON     ", 8) != 0)
        fail("CON name wrong");
    if (! (dd->attr & CHAR_DEV))
        fail("CON attr wrong");
    FREE_MAP(dd);

    /* CLOCK$ is also pointer, so need to map */
    dd = (DeviceDriver far *) MAP(doslist->clock, sizeof(DeviceDriver));
    if (_fmemcmp(dd->u.name, "CLOCK$  ", 8) != 0)
        fail("CLOCK$ name wrong");
    if (! (dd->attr & IS_CLOCK))
        fail("CLOCK$ attr wrong");
    FREE_MAP(dd);
#endif /*PARANOID*/

    /*
       Print out device chain  thanks to the MAP, FREE_MAP, GET_REAL,
       and YIELD macros, this works in real mode DOS or in protected mode
       Windows. Old real mode only code looked like this:
            do {
```

```
                printf("%Fp\t", dd);
                if (dd->attr & CHAR_DEV)
                    printf("%.8Fs\n", dd->u.name);
                else
                    printf("Block dev: %u unit(s)\n", dd->u.blk_cnt);
                dd = dd->next;
            } while (FP_OFF(dd->next) != 1);
    */
    for (dd = &doslist->nul;;)
    {
        printf("%Fp    ", GET_REAL(dd)); /* print real mode addr */
        if (dd->attr & CHAR_DEV)
        {
#ifdef __BORLANDC__
            // Borland C++ printf can't handle non-terminated strings
            char buf[9];
            _fmemcpy(buf, dd->u.name, 8);
            buf[8] = '\0';
            printf("%s\r\n", buf);
#else
            printf("%.8Fs\r\n", dd->u.name);
#endif
        }
        else
            printf("Block dev: %u unit(s)\r\n", dd->u.blk_cnt);
        next = dd->next;            /* get next pointer */
        /* first time through, this will free selector to doslist */
        FREE_MAP(dd);               /* THEN free rmode seg */
        if (FP_OFF(next) == 0xFFFF) /* is there a next? */
            break;
        dd = (DeviceDriver far *) MAP(next, sizeof(DeviceDriver));
        YIELD();    /* no message loop in this program, so yield */
    }

#ifdef WINDOWS
{
    WORD mapped;
    if (mapped = get_mapped())
        printf("Error: %u remaining mapped selectors\r\n", mapped);
    show_display();
    return mapped;  /* 0 indicates success */
}
#else
    return 0;
#endif
}
```

Figure 3-6: DEV Under Windows

```
011A:0008    NUL
1A51:0002    Block dev: 1 unit(s)
1A52:0004    Block dev: 6 unit(s)
1A53:0006    Block dev: 3 unit(s)
CC2C:0000    OBLSSYS$
1328:0000    MSCD001
C884:0000    MS$MOUSE
02DD:0000    Block dev: 1 unit(s)
0298:0002    386MAXS$
029A:0000    EMMXXXX0
026E:0000    SETVERXX
0255:0000    Block dev: 6 unit(s)
0D72:0003    CON
0073:0005    AUX
0074:0007    PRN
0075:0009    CLOCK$
```

```
0076:0008    Block dev: 3 unit(s)
0077:0008    COM1
0078:000D    LPT1
0079:000F    LPT2
007A:0008    LPT3
007C:000A    COM2
007D:000C    COM3
007E:000E    COM4
103E:0000    EMMXXXX0
```

An item worthy of note here is the second EMMXXXX0 expanded memory device at the very end of the list. As noted in Chapter 1 (see "Implementing DOSMGR Functions"), V86MGR uses the DOSMGR Add Device function to add its emulated EMM driver onto the end of the DOS device chain.

Truename

So far, we've been calling undocumented DOS functions from Windows with real_int86x(), and mapping a segmented real mode pointer with map_real(). This works fine for functions such as INT 21h AH=52h, but it isn't always the appropriate way to call an undocumented DOS function from protected mode.

For example, the undocumented DOS Truename function (INT 21h AH=60h) expects a pointer to an ASCIIZ pathname in DS:SI; this function places the "canonical" fully qualified version of the pathname in a buffer pointed at by ES:DI. Windows does not support this function in protected mode, so you must use real_int86x() or some other derivative of INT 31h AX=0300h to make the INT 21h AH=60h call from real or V86 mode. But when setting up the registers for the real mode call, what values should you put in DS:SI and ES:DI? Your documents can't use protected mode pointers because the whole point of using DPMI function 0300h is to generate a real or V86 mode interrupt. A protected mode pointer would be misinterpreted by DOS as a real mode pointer. Obviously, then, you must put real mode pointers in DS:SI and ES:DI. But where do you get those real mode pointers? A moment's consideration will reveal that our old standbys map_real() and get_real_addr(), are not useful here.

Consider how a truename() function would work if there were a nice C interface to DOS:

```
char *src = "c:\\this\\is\\some\\path",
char dest[128],
if (truename(src, dest))
    printf("Truename of %s is %s\n", src, dest),
```

In real mode DOS the truename() function could be implemented more or less like this (see Chapter 8 for a better version):

```
char far *truename(char far *src, char far *dest)
{
    _asm push ds
    _asm push di
    _asm push si
    _asm les di, dest
    _asm lds si, src
    _asm mov ah, 60h
    _asm int 21h
    _asm pop si
    _asm pop di
    _asm pop ds
    _asm jc error
    return d,
error:
    return (char far *) 0;
}
```

In protected mode we want truename to work the same way. Internally the function will somehow have to turn the src and dest parameters into real mode pointers. How? In a protected mode program src and dest will almost certainly be located in extended memory.

But there *isn't* any real mode equivalent to a protected mode pointer whose selector has a base address in extended memory. Thus it seems there is no way for truename to translate correctly its protected mode parameters to real mode for use by DOS. In fact there isn't. What truename must do is take the ASCIIZ string to which src points and copy it into a small buffer located in conventional memory. Truename must pass the real mode address of this buffer to DOS. And it needs to create another buffer into which DOS can copy the canonicalized results before returning. truename must again copy the result from the conventional memory results buffer to the caller's dest pointer.

The real question then is how to allocate conventional memory from a protected mode program. There are numerous ways to do this. For example, you could use real mode INT 21h AH=48h. Calling INT 21h AH=48h in a protected mode program allocates extended memory, and certainly returns protected mode selectors. But calling the function from real or V86 mode with real or V86 CS would of course yield the real mode paragraph address of a block of conventional memory. You could then map a descriptor to get a protected mode selector to this conventional memory. You would manipulate these two memory blocks with a protected mode address and pass the original real mode paragraph address to DOS. The conventional memory block then acts as a transfer buffer.

Fortunately there is a simpler way to allocate conventional memory from protected mode. The DPMI Allocate DOS Memory Block function (INT 31h AX=0100h) allocates a conventional memory block and returns both the real mode paragraph address and protected mode selector pair that you need to treat the block as a transfer buffer. DPMI also provides for DOS Memory Block (INT 31h AX=0101h) and Resize DOS Memory Block (INT 31h AX=0102h) functions. The Windows API provides two similar functions, GlobalDOSAlloc and GlobalDOSFree. Of course, there's nothing magical about these functions. They don't allocate any memory that you couldn't allocate for yourself. For example, Allocate DOS Memory Block (DPMI or Windows) uses a protected mode function (INT 21h AH=48h).

PROT.C (Listing 3.16) provides a protected mode function called alloc_dos_mem that uses the DPMI or Windows DOS allocation functions. It's easiest to show how to use this function when it's used to implement TRUENAME.C (Listing 3.20) contains a protected mode truename function called from Windows. It's a testbed for trying it out. Simply run TRUENAME with a command line argument. Then Windows programs can access the file. TRUENAME displays a message box with the results.

Listing 3-20: TRUENAME.C for Windows

```
/*
TRUENAME.C -- for Windows
Andrew Schulman, February 1993
bcc -W -DWINDOWS  2 truename,c win_app lib
*/

#include <stdlib.h>
#include <stdio.h>
#include <string.h>
#include <ctype.h>
#include <dos.h>
#include "windows.h"
#include "printf.h"
#include "prot.h"
#define DEST_OFS    128
#define SRC_OFS     0
void fail(char *s) { MessageBox(NULL, s, "TRUENAME", MB_OK); exit(1); }

/* see real mode version in DISKSTUF.C (Listing 8-4) */
char far *truename(char far *src, char far *dest)
{
```

```
    RMODE_CALL r;
    char far *s2, far *fp,
    WORD para, sel,

    /* INT 21h AH=60h doesn't like trailing or leading blanks */
    while (isspace(*src)) src++;
    s2 = src;
    while (*s2) s2++,
    s2 --,
    while (isspace(*s2)) *s2-- = '\0';

     * A lnc 256 bytes conventional memory   first 128 to transfer in src;
       second half to transfer back dest */
    if (! alloc_real_seg(256, &para, &sel))
        fail( Couldn't allocate conventional memory' ),

    fp = (char far *) MK_FP(sel, SRC_OFS),
    _fstrcpy(fp, src);  /* use prot-mode sel addr in program */

    /* Generate real mode 21/60 */
    memset(&r, 0, sizeof(r));
    r.eax = 0x6000,
    r.ds = r.es = para;  /* pass real mode para addr to DOS */
    r.esi = SRC_OFS,
    r.edi = DEST_OFS;
    if (! dpmi_rmode_intr(0x21, 0, 0, &r))
        fail( DPMI real mode interrupt failed!"),   //oops, should call free_real_seg

    if (r.flags & 1)    /* If carry set */
        _fstrcpy(dest, "<Invalid> ),
    else
         fstrcpy(dest, (char far *) MK_FP(sel, DEST_OFS)),

    /* copied to caller's dest, don't need conventional-memory
       transfer buffer anymore */
    if (! free_real_seg(sel))
        fail( Couldn't free conventional memory!"),

    return dest,
}

int PASCAL WinMain(HANDLE hInst, HANDLE hPrevInst,
    LPSTR lpszCmdLine, int nCmdShow)
{
    char buf[128], dest[128],

    if (! (GetWinFlags() & WF_PMODE))
        fail( This program requires Windows Enhanced or Standard mode"),

    if (! lpszCmdLine && *lpszCmdLine)
        fail( syntax: truename <pathname>"),
    sprintf(buf, "TRUENAME %Fs", lpszCmdLine);
    open_display(buf),
    printf( %Fs\n , truename(lpszCmdLine, dest)),
    show_disp ay(),
    return 0,
}
```

For example, if you load the DOS command SUBST E: C:\DOS before starting Windows, then run TRUENAME E:\BAR, you'll produce the results C:\DOS\BAR.

Note that the protected mode version of truename does. After allocating 256 bytes with the real seg... it copies the src string to the conventional memory buffer, using the buffer's protected mode address. Truename then calls INT 21h AH=60h in real mode, passing in the buffer's real mode address. When function 60h returns by way of the DPMI simulated real mode interrupt call,

truename copies DOS's reply to the caller's dest and frees up the transfer buffer. truename handles all this activity from its caller. It is almost as if DOSMGR implemented Function 60h at the first place.

Windows and the PSP

There's something annoying about porting programs such as TRUENAME to Windows. After you get all the simulated real-mode interrupts and segment values and stack correct, you're left with a weird thing that isn't quite different enough that you could do each more easily under DOS. You're going through all that extra work only to produce the same old results.

When porting real DOS programs to Windows, don't do such a stupid thing. You must consider how whatever you're porting can take advantage of Windows. A good example is the classic MEM utility, which works and displays the DOS Memory Control Block chain. Chapter 4 presents an extensive example of such a utility, UDMEM. Naturally, we could take a DMEM and turn it into a Windows program using tricks to create temporary protected-mode pointers to each MCB. But what would be the point of that? Windows memory management is so fundamentally different from plain vanilla DOS. A Windows version of UDMEM wouldn't reveal anything about Windows and would not provide a new light on the MCB chain either.

One of the things a MEM utility can display are PSPs. How do you find a PSP under Windows? A simple call to WinExec will actually create PSPs for all the EXEs under active Windows, and you see entries for CON, Windows executables such as WIN.COM, WINSRV.EXE, and KRNL386.EXE, but something is clearly missing. As noted earlier, every Windows task has an associated PSP. Well then, where are these PSPs? They can't be in conventional memory because that is used for segments and *linear info* PSPs. As we noted earlier, a Windows task's open files, environment, PSP, and even the real-mode DOS XFA are in a single extended Windows port of UDMEM won't find these PSPs for Windows programs. Why? Because when the Windows kernel allocates these PSPs, it gets them from memory other than conventional memory. Therefore, a PSP's segment value doesn't point to a location in the first megabyte of memory, and Walking the MCB chain won't find these Windows PSPs.

There's a separate chain of Windows PSPs associated with the Windows task database, and I linked through this private chain to find the PSPs. I could then offset 42 into the PSP for the WinOldAp module responsible for running executables under DOS programs under Windows. Windows programs don't previously maintained a linked list of PSPs according to DOS specs. Simple programs in DOS exist for a MCB walker or Windows equivalent, these Windows specific tricks don't apply.

Listing 3-21 shows a Windows PSP viewer. WINPSP.C is a program that loops through (using the normal MCB chain) all the memory blocks. Using Windows' ToolHelp library to walk the MCB chain, WINPSP.C examines each code segment to see if its selector value matches a PSP's segment value. If so, it displays the PSP's segment value and the PSP's parent PSP segment value. This program is similar to the *undocumented Windows* example in Chapter 5. In that program, a Windows PSP chain is found using the task pointers stored at offset 42h.

Listing 3-21: WINPSP.C Walks the Windows PSP Chain

```
/*
WINPSP.C
Andrew Schulman, April 1993
From "Undocumented DOS", 2nd edition (Addison-Wesley, 1993)

Uses EasyWin:
bcc -W -Z winpsp.c prot.c toolhelp.lib
*/

#include <stdlib.h>
#include <stdio.h>
#include <string.h>
#include <dos.h>
#include "windows.h"
#include "prot.h"
#include "toolhelp.h"
```

```
#ifdef __cplusplus
extern "C" BOOL FAR PASCAL IsWinOldApTask(HANDLE hTask);
#else
extern BOOL FAR PASCAL IsWinOldApTask(HANDLE hTask);
#endif

#define MAP(ptr, bytes)     map_real((ptr), (bytes))
#define FREE_MAP(ptr)       free_mapped_linear(ptr)
#define GET_REAL(ptr)       get_real_addr(ptr)

#pragma pack(1)

typedef struct {
    BYTE type,
    WORD owner,    /* PSP of the owner */
    WORD size,
    BYTE unused[3],
    BYTE name[8],  /* in DOS 4+ */
    } MCB;

WORD get_first_mcb(void)
{
    RMODE_CALL r;
    memset &r, 0, sizeof(r));
    r.eax = 0x5200,
    if (dpmi_rmode_intr(0x21, 0, 0, &r))
    {
        // Extract seg of first MCB from SysVars  Note that this is
        // at sysvars[-2]  You can't call map_real() on sysvars, and
        // then back up 2! You must map in sysvars-2 to begin with.
        WORD far *tmp = (WORD far *) MAP(MK_FP(r.es, (WORD) r.ebx-2), 2);
        WORD first_mcb = *tmp,
        FREE_MAP tmp),
        return first_mcb,
    }
    else
        return 0,
}

WORD count_open_files(BYTE far *jft, WORD num_files)
{
    WORD open_files = 0,
    BYTE far *fp;
    int i,
    // count number of open files in a Job File Table (JFT)
    for (i=0, fp=jft; i<num_files; i++, fp++)
        if (*fp != 0xFF)
            open_files++,
    return open_files,
}

void display_psp WORD psp_seg, BYTE far *psp, MCB far *mcb)
{
    BYTE far *real_jft;
    BYTE far *prot_jft,
    WORD num_files;

    printf("%04X\t%04X", psp_seg, mcb->size);
    if (_osmajor >= 4)
    {
        char buf[9],
        _fmemcpy(buf, mcb->name, 8),
        buf[8] = '\0',
        if  *buf)
            printf( \t%-8s", buf);
    }
    real_jft = *((BYTE far * far *) &psp[0x34]);
    num_files = *((WORD far *) &psp[0x32]),
    prot_jft = (BYTE far *) MAP(real_jft, num_files);
```

```
    printf(" \tZFp (%u files, %u open)\n",
        real_jft, num_files,                    /* print real mode addr */
        count_open_files(prot_jft, num_files)), /* use pmode addr */
    FREE_MAP(prot_jft),
}

void fail(char *s) { printf("%s\n", s); exit(1); }

main()
{
    TASKENTRY te,
    BYTE far *maybe_psp,
    MCB far *mcb,
    WORD mcb_seg,
    WORD mapped,
    BOOL ok;

    printf( ----------------------\nDOS apps:\n");

    // walk DOS MCB chain, looking for PSPs
    if (! (mcb_seg = get_first_mcb()))
        fail("Can't get MCB chain!");
    for (;;)
    {
        mcb = (MCB far *) MAP(MK_FP(mcb_seg, 0), sizeof(MCB)),
        maybe_psp = (BYTE far *) MAP(MK_FP(mcb_seg + 1, 0), 512),
        if (*((WORD far *) maybe_psp) == 0x20CD) // look like a PSP
        {
            if ((mcb_seg + 1) == mcb->owner)      // regular DOS app PSP
                display_psp(mcb_seg + 1, maybe_psp, mcb);
        }
        FREE_MAP(maybe_psp),
        if (mcb->type == 'Z')
            break;                                // end of list
        mcb_seg = mcb_seg + mcb->size + 1;        // walk list
        FREE_MAP(mcb),
    }
    FREE_MAP(mcb),                                // free last one
    mapped = get_mapped();
    if (mapped != 0)
        printf( ERROR! %u mapped selectors remaining!\n", mapped),

    printf("----------------------\nWindows apps:\n"),

    // now walk Windows task list, and extract PSPs
    te.dwSize = sizeof(te);
    ok = TaskFirst(&te),
    while (ok)
    {
        BYTE far *tdb = (BYTE far *) MK_FP(te.hTask, 0),
        WORD prot_psp = *((WORD far *) &tdb[0x60]),
        WORD real_psp   GetSelectorBase(prot_psp) >> 4,
        if (*((WORD far*)MK_FP(prot_psp,0))==0x20CD) // really a PSP
        {
            BYTE far *psp = (BYTE far *) MK_FP(prot_psp, 0),
            BYTE far *real_jft = *((BYTE far * far *) &psp[0x34]),
            WORD num_files = *((WORD far *) &psp[0x32]);
            BYTE far *prot_jft   (BYTE far *) MAP(real_jft, num_files),

            // Windows-specific fields in PSP!
            WORD back_ptr = *((WORD far *) &psp[0x42]);
            WORD flags = *((WORD far *) &psp[0x48]);

            printf( %04X\t %-8s , real_psp, te.szModule),

            if (IsWinOldApTask(te.hTask) && (! (flags & 1)))
                fail("IsWinOldApTask flag weirdness!"),
            putchar( (flags & 1) ? '*' : ' ' );    // IsWinOldApTask

            printf(" \tZFp (%u files, %u open)\n",
```

```
                real_jft, num_files,    // print out real mode addr
                count_open_files(prot_jft,num_files)); // use pmode addr
            FREE_MAP(prot_jft);
        }
        ok = TaskNext(&te);
    }
    printf("                    ----------\nFollow PSP backlinks \n");
    {
        WORD prot_psp, real_psp, next_psp,
        BYTE far *psp,
        prot_psp = GetCurrentPDB();
        while (prot_psp != 0)
        {
            real_psp = GetSelectorBase(prot_psp) >> 4,
            next_psp   *((WORD far *) MK_FP(prot_psp, 0x42)),
            printf("%04X (%04X) -> %04X\n", prot_psp, real_psp, next_psp),
            prot_psp = next_psp,
        }
    }
    return 0;
}
```

Figure 3.7 shows sample WINPSP output. In addition to displaying the real mode paragraph addresses for each PSP and its name, WINPSP shows the size in paragraphs of the MCB based on Windows' NEs. Since Windows PSPs don't have MCBs the size field is blank. Any number here would be meaningless anyway since Windows programs can allocate gobs and gobs of extended memory. WINPSP also shows the address of the all important Job Table JHT associated with each PSP and displays the size of the JHT. Finally, WINPSP walks the JHT to determine the number of open files for each process.

Figure 3.7: Sample Output from WINPSP

```
DOS apps:
1180    0094    COMMAND         1180 0018 (20 files, 5 open)
1242    0102    DOSKEY          1242 0018 (20 files, 5 open)
1345    020D    WINICE          1345 0018 (20 files, 5 open)
1550    0055    win             155D 0018 (20 files, 5 open)
15BF    0341    win386          15BF 0018 (20 files, 5 open)
1900    85F3    KRNL386         278A 000D (32 files, 18 open)
 ----    ----------------
Windows apps
257C            WINOLDAP*       257C 0018 (20 files, 5 open)
269C            DRWATSON        269C 0018 (20 files, 5 open)
4672            WINFILE         256A 0000 (30 files, 5 open)
2702            SH              2702 0018 (20 files, 5 open)
2734            WINPSP          2734 0018 (20 files, 5 open)
--- - ---
Follow PSP backlinks
11CF (2734) -> 1297
1297 (2702) -> 12F7
12F7 (269C) -> 1437
1437 (257C) -> 1817
1817 (4672) -> 00C7
00C7 (1900) -> 0000
```

WINPSP examines a Windows specific flag word at offset 48h in the PSP to determine when it has a DOS box. It marks these with an asterisk. Windows itself uses this field in the useful undocumented IsWinOldApTask function (see *Undocumented Windows* Chapter 5). We use IsWinOldApTask as well as the ability to get at DOS boxes from Windows in Listing 3.28 below. WINPSP displays all

DOS boxes with the name WINOLDAP. It would of course be more useful to display the name of whatever program is running in that DOS box, or at least the DOS box's window title.

Peeking at DOS Boxes from a Windows Program

Speaking of DOS boxes, it would be nice if Windows programs had an easier time getting at them. While it's a good thing that each virtual machine is protected mode has its own address space, a pointer such as 1234:567Eh in a DOS box has no relationship to 1234:567Eh in another DOS box or in a Windows program. That's the whole point. This makes it difficult for Windows programs to communicate with non-Windows programs. Such communication would be extremely useful, given that Enhanced mode provides preemptive multitasking for non-Windows programs. Windows programs are only cooperatively multitasked.

Fortunately, while each VM has its own segment:offset address space, all the VMs are connected at a lower level in the linear address space. By mapping to linear addresses first, a protected DOS box or a Windows program can peek or poke data in other VMs. Likewise, protected mode DOS applications can map to linear addresses to access data in the Windows address space.

For example, we noted a second ago that a useful thing for WINPSP would be the value of the program segment prefix (PSP) of the suspended DOS box. To do this, WINPSP would need to get the *real-mode* segment address of the suspended DOS box's PSP. It could then add this address to the linear address of the DOS box's virtual data structures and then create protected mode pointers to these structures. (Or the map linear function could do it.) Listing 3-22 presents pseudocode for these steps.

Listing 3-22: Pseudocode for Examining the Current PSP in Other VMs

```
sda = get_sda();
for each DOS box
    high_lin = somehow get DOS box's high linear address,  // see below

    // make linear address from SDA pointer
    sda_lin = MK_LIN(sda);

    // add together to get linear address of SDA in DOS box
    vm_sda_lin = high_lin + sda_lin;

    // make protected mode pointer to SDA in DOS box
    vm_sda = map_linear(vm_sda_lin, sizeof SDA);

    // extract current PSP from DOS box's SDA
    vm_curr_psp = vm_sda[0x10];
    free_mapped_linear(vm_sda);      // done with SDA

    // get linear address of current PSP in DOS box
    #define SEG_TO_LIN(x)   ((x) * 0x10)
    vm_curr_psp_lin = high_lin + SEG_TO_LIN(vm_curr_psp);

    // make protected mode pointer to current PSP in DOS box
    vm_psp = map_linear(vm_curr_psp_lin, sizeof PSP);

    // extract environment segment from DOS box's current PSP
    env_seg = vm_psp[0x2C];
    free_mapped_linear(vm_psp);      // done with PSP

    // make protected mode pointer to current environment in DOS box
    vm_env_lin = high_lin + SEG_TO_LIN(env_seg);
    vm_env = map_linear(vm_env_lin, 0xFFFF);

    do usual stuff to walk env to find program name (see Chapter 7);
    display program name;
    free_mapped_linear(vm_env);
```

Let's go over that again. From a program running in one VM (either a Windows program or a DOS program), we want to be able to get at data in other VMs. For example, a Windows program might want to access DOS internal data structures, such as the SDA or SysVars or CDS's or DOS

box. Because of the way that DOSMGR works, many of these structures *must* be at the same real mode segment:offset address in each VM. As Chapter 1 noted, DOSMGR assumes that even structures such as the CDS are not going to move. You can derive this real mode segment:offset address to a linear address using the familiar *linear = segment * 16h + offset* rule. MK_LIN, see Listing 3.1. To find the structure in a particular VM, you must add this linear address onto the VM's high linear address.

The high linear address is the offset of the VM's address space within the entire Enhanced mode address space. The key point is that this address is valid even when the VM is not running. For example, let us record a linear address 12345h when a VM is running. If a VM's high linear address is 12345h when the VM is not running. The current VM's memory has a base address of 0. We've been using segment:offset addresses to locate data, but since we've always been accessing data in our own VM, without even knowing which VM we were in to begin with, the high linear part. After all, if our program was running, then it's VM was by definition the current VM.

So, it's easy to get the all important high linear address for each VM, leaving aside for the moment how a program gets one of these addresses. Note that debuggers such as WINICE displays these addresses:

```
vm
VM Handle   Status      High Addr   VM ID       Current Regs
805C1000    00004000    81800000    00000002    8046BF70
80481000    00001062    81400000    00000001    80010650
```

The system VM's VM ID is always one. System VM is where all Windows applications run. Another VM is the DOS box. We can see that the System VM's high linear address is this number 81400000h, and that there is the DOS box VM ID 2 which has the high linear address 81800000h. Another words, in this example the DOS box's memory starts at 81800000h. A Windows program can't peek and poke this memory directly, it must map linear to that address. You can now see why we needed a segment:offset to access separate from map real. From here, enormously powerful, we can access the full 4 gigabytes of address space. Access to physical addresses this much doesn't have two gigabytes of memory!

Notice that WINICE displays a *VM handle*. VM handles are unique identifiers for each VM, but a VM handle is more than that. The number happens to be the linear address of the VM's *control block*. The VM control block is a large data structure, only a few fields of which are documented. Examining each reveals that the WINICE VM command does nothing more than displaying the VM's high linear address. Listing 3.2 shows how a VM_CB structure that shows this and other fields. Given a VM handle, then one can get the high linear address with the following code. This is how the "somehow get DOS box's high linear address" line in Listing 2.22.

```
DWORD vm_handle = somehow_get_vm_handle();
VM_CB far *vm_cb = map_lin_near(vm_handle, sizeof(VM_CB));
DWORD high_linear = vm_cb->high_linear;
free_mapped_lin_near(vm_cb);
```

So now all we need is to get VM handles. This is the only difficult part. Fortunately, there is a way. VMM provides several functions for developers that return VM handles, including Get Cur VM Handle, Get Sys VM Handle, Get Next VM Handle, follow the VM chain, and Get Sys VM Handle. Get Next VM Handle. Each of these functions returns a VM handle in the EBX register.

Great! Now I only have to write some way to call these functions from a Windows or DOS program. Unfortunately, VMM and VxD functions do not appear in the WINDOWS.H header file. They do not even seem to be part of the normal Windows programming repertoire.

Fortunately, we can still call these or any other VMM or VxD functions from a normal Windows or DOS program. Recall that normal programs inadvertently call VMM and VxDs all the time. VxDs

such as DOSMGR allocate callbacks and attach these to interrupts. Whenever a Windows program calls INT 21h (for example, a seemingly innocuous call that ends up running some 32-bit Ring 0 code in DOSMGR. Well-behaved programs can also *legitimately* call into VxDs too. Windows provides a service called Get Device Entry Point Address (accessed via INT 2Fh AX=1684h) which gives you the ID number of a VxD and returns a far pointer that the program can call to access services provided by the VxD.

This means that, for example, we could write a VxD to provide VMM-style services to Windows and DOS programs. A program might call function 0 to get the current VM handle, function 1 to get the next VM, and function 2 to get the System VM handle. The VxD would of course implement these functions by calling the VMM services. There's nothing magic about the Windows or DOS program. Clearly, VxDs aren't just for devices.

We can't do this with the tools we've developed through this book. Why write a VxD just to get at three functions? Next week or next month, we'll want to get at a different three functions. It's instead possible to implement a *generic* VxD which lets Windows and DOS programs access the functions in VMM or a VxD. Here we use the generic VxD to get at the three VMM handle functions provided by VMM. This barely shows off the capabilities of the generic VxD, which could be the subject of an entire book. For a taste of the kinds of things the generic VxD can do, an explanation of how it works, and a look at its source code, see "Calling VxD Functions and VMM Services Easily Using Our Generic VxD," *Microsoft Systems Journal*, February 1993.

So now do we have a function to get a VM handle (pseudocode above). This is provided by VMMWALK.C (see VMMWALK.ASM shown in Listings 3-23 and 3-24). VMMWALK provides a VMWALK function which takes a pointer to a per-VM callback. Using the generic VxD, VMMWALK uses Get Sys VM Handle and Get Next VM Handle to enumerate all VMs in the system. For each virtual machine, VMMWALK maps a copy of the VM handle data structure into the caller's address space and calls the passed callback to allow the caller to examine the VM handle data. The caller is free to read anything through the linear address, and can do what it wants.

Listing 3-23: VMWALK.C

```
/*
VMWALK.C -- Enumerates VM handles, using generic VxD
Andrew Schulman, February 1993
From  Undocumented DOS , 2nd edition (Addison-Wesley, 1993)
*/

#include <stdlib.h>
#include <string.h>
#include <dos.h>
#ifdef WINDOWS
#include "windows.h"
#endif
#include "prot.h"
#include "vxdcalls.h"
#include "vmwalk.h"

int vmwalk(WALKFUNC walkfunc)
{
    DWORD sys_vm = GetSysVMHandle();
    void far *vm_cb;
    VM_CB my_vm_cb;
    DWORD vm;
    int num_vm;
    for (vm=sys_vm, num_vm=0;; num_vm++)
    {
        set_vm(0);  // in case app fiddled with it
        vm_cb = map_linear(vm, sizeof(VM_CB));
        _fmemcpy(&my_vm_cb, vm_cb, sizeof(VM_CB));
        free_mapped_linear(vm_cb);
        if (! (*walkfunc)(vm, &my_vm_cb))
```

```
            return num_vm;
        if ((vm = GetNextVMHandle(vm)) == sys_vm)
            break;  // circular list
    }
    return num_vm;
}

DWORD GetSysVMHandle(void)
{
    VxDParams p;
    p.CallNum = Get_Sys_VM_Handle;
    return (VxDCall(&p)) ? p.OutEBX : 0;
}

DWORD GetCurVMHandle(void)
{
    VxDParams p;
    p.CallNum = Get_Cur_VM_Handle;
    return (VxDCall(&p)) ? p.OutEBX   0;
}
DWORD GetNextVMHandle(DWORD vm)
{
    VxDParams p;
    p.CallNum = Get_Next_VM_Handle;
    p.inEBX   vm;
    return (VxDCall(&p)) ? p.OutEBX . 0;
}

// The next functions do nothing but add vm_cb->CB_High_Linear
// onto a linear address, but they make it a lot easier to work with
// multiple VMs.
DWORD get_vm_base(DWORD vm)
{
    VM_CB far *vm_cb;
    DWORD base;
    if (vm == 0) return 0;  // stay in current VM
    vm_cb   (VM_CB far *) map_linear(vm, sizeof(VM_CB));
    base = vm_cb->CB_High_Linear;
    free_mapped_linear(vm_cb);
    return base;
}

void set_vm(DWORD vm)   // sets base address for map_linear
{
    set_base(get_vm_base(vm));
}

void far *map_real_vm(DWORD vm, void far *fp, WORD bytes)
{
    return map_linear(get_vm_base(vm) + MK_LIN(fp), bytes);
}

void far *map_linear_vm(DWORD vm, DWORD lin_addr, WORD bytes)
{
    return map_linear(get_vm_base(vm) + lin_addr, bytes);
}

#ifdef TESTING
#include <stdio.h>

BOOL walkfunc(DWORD vm, VM_CB far *vm_cb)
{
    printf("%08lX   VM #%lu  lin=%08lXh  crs=%08lXh\n",
        vm,
        vm_cb->CB_VMID,
        vm_cb->CB_High_Linear,
        vm_cb->CB_Client_Pointer);
    return 1;
}
```

```
void fail(const char *s,    ) { printf("%s\n", s), exit(1); }
#ifdef DPMI_APP
#pragma argsused
int real_main(int argc, char *argv[])   { return 0, }
#pragma argsused
int pmode_main(int argc, char *argv[])  { return vmwalk(walkfunc); }
#else
int main()                              { return vmwalk(walkfunc); }
#endif
#endif /*TESTING*/
```

Listing 3-24: VMWALK.H

```
/*
VMWALK.H -- See VMWALK.C
Andrew Schulman, February 1993
From "Undocumented DOS", 2nd edition (Addison-Wesley, 1993)
*/

// the first four fields are documented in DDK VMM.INC
typedef struct {
    DWORD CB_VM_Status,
    DWORD CB_High_Linear,
    DWORD CB_Client_Pointer;
    DWORD CB_VMID,
    BYTE other[0x1D0],   / e g , vm->next at VM+68h
    } VM_CB;             // Virtual Machine Control Block

// Known VM_CB offsets in Windows 3.1
// 00h  status
// 04h  high linear
// 08h  client pointer
// 0Ch  VM ID
// 14h  Get_Last_Updated_VM_Exec_Time return
// 18h  page tables
// 64h  Get_Cur_PM_App_CB return
// 68h  Get_Next_VM_Handle return
// 8Ch  instance data struct
// 10Ch A20 wrap flag

// For more on the VM CB, see the two part article by
// Kelly Zytaruk in Dr  Dobb's Journal, Dec  1993 and Jan  1994
#define NEXT_VM(vm_cb)  *((DWORD far*)((BYTE far*)vm_cb+0x68))

typedef BOOL (*WALKFUNC)(DWORD vm, VM_CB far *),
int vmwalk(WALKFUNC walkfunc);
extern BOOL walkfunc(DWORD vm, VM_CB far *vm_cb),   // app to provide

#ifndef DPMI_APP
// for Windows-based WVMWALK (without generic VxD, 3 1 Win apps only!)
typedef BOOL (*WWALKFUNC)(HWND hwnd, char *title, DWORD vm,
   VM_CB far *vm_cb);
int wvmwalk(WWALKFUNC walkfunc);
extern BOOL wwalkfunc(HWND hwnd, char *title, DWORD vm, VM_CB far *vm_cb),
#endif

DWORD GetSysVMHandle(void),
DWORD GetCurVMHandle(void),
DWORD GetNextVMHandle(DWORD vm);

void set_vm(DWORD vm),  // sets base address for map_linear
void far *map_real_vm(DWORD vm, void far *fp, WORD bytes),
void far *map_linear_vm(DWORD vm, DWORD lin_addr, WORD bytes),
```

Given a VM handle, the GetNextVMHandle function returns the next VM in the system. vmwalk starts off its VM enumeration by calling GetFirstVMHandle. The VM list is circular, so when vmwalk finds itself with the System VM handle again, it is finished.

But how do GetNextVMHandle and GetNextVMHandle work in the first place? These functions are wrappers around calls to VxDCall0. This function—we'll see the code for it in a moment—is the C interface to the generic VxD. It expects to be passed a VxDParams structure, which contains all the information the generic VxD needs to make a VMM or VxD call on an application's behalf.

For example, the DDK documents Get Next VM Handle as taking a VM handle in the 32-bit EBX register and returning the next VM handle also in the EBX register. The VxDParams structure contains a union of 32-bit registers for both function input and output. It also contains a dwNo field, which holds the function's magic number. Get Next VM Handle is defined as an InfoCmd, so its function number is 0x01000301. These function numbers include the VxD ID number. VMM is considered to be VxD 1.

Any program that wants to use the generic VxD must #include VXDCALLS.H, and link with VXDCALLS.C (see Listings 3.25 and 3.26). The generic VxD itself is the file VXD.386, which must be installed before it can be used. It should be installed in C:\undocdos\chap3\vxd\386 in the [386Enh] section of SYSTEM.INI.

Listing 3.25: VXDCALLS.C

```
/*
VXDCALLS.C -- C interface to generic VxD (VXD.386)
Andrew Schulman, February 1993
From "Undocumented DOS", 2nd edition (Addison-Wesley, 1993)
Abbreviated from version in Microsoft Systems Journal, February 1993
*/

#ifndef DPMI_APP
#include "windows.h"
#endif

#include <dos.h>
#include "vxdcalls.h"

static void far *API = 0;
static BOOL API_is_V86 = 1;
static char *requires_msg    "This program requires VXD 386",

extern void fail(const char *s, ...);

/* Get entry point for the VxD API using Int 2Fh AX=1684h */
api_entry GetVxDAPI(WORD vxd_id)
{
    _asm push di
    _asm mov ax, 1684h
    _asm mov bx, vxd_id
    _asm xor di, di
     asm mov es, di
     asm int 2Fh
    _asm mov ax, di
    _asm mov dx, es
     asm pop di
    // returns in DX:AX
}

// This is only accurate with DPMI
BOOL IsProtMode(void)
{
    unsigned _ax;
    _asm mov ax, 1686h
     asm int 2Fh
    _asm mov _ax, ax
    return (! _ax),
}

/* check if generic VxD installed */
BOOL GenericVxDInstalled(void)
{
```

```
    return (GetVxDAPI(Generic_Dev_ID) | (api_entry) 0),
}
static void InitVxDAPI(void)
{
    if (! API)
    {
        if (! (API = GetVxDAPI(Generic_Dev_ID)))
            fail(requires_msg),
        API_is_V86 = (! IsProtMode()),
    }
    else if (API_is_V86 && IsProtMode())
    {
        // API was last set in V86 mode, and we are now in protected mode
        API = GetVxDAPI(Generic_Dev_ID),    // get PM API
        API_is_V86 = 0;
    }
}
BOOL VxDCall(VxDParams far *fp)
{
    InitVxDAPI(),
    _asm push es
    _asm les bx, dword ptr fp
    _asm mov ax, VXD_VxDCall
    _asm call dword ptr [API]
    _asm pop es
    _asm jc Error
    return TRUE;
Error:
    return FALSE,
}
BOOL VxDPushCall(VxDPushParams far *fp)
{
    InitVxDAPI(),

    _asm push es
    _asm les bx, dword ptr fp
    _asm mov ax, VXD_VxDPushCall
    _asm call dword ptr [API]
    _asm pop es
    _asm jc Error
    return TRUE;
Error:
    return FALSE,
}
```

Listing 3-26: VXDCALLS.H

```
/*
VXDCALLS.H -- See VXDCALLS.C
Andrew Schulman, February 1993
From "Undocumented DOS", 2nd edition (Addison-Wesley, 1993)
Abbreviated from version in Microsoft Systems Journal, February 1993
*/

#ifdef DPMI_APP
typedef int BOOL,
typedef unsigned short WORD,
typedef unsigned long DWORD,
#endif

#ifndef FALSE
#define FALSE   0
#define TRUE    (! FALSE)
#endif
```

```
/* Structure used with VxDCall */
typedef struct {
    DWORD CallNum,
    DWORD Reserved1;
    DWORD InEAX, InEBX, InECX, InEDX, InEBP, InESI, InEDI,
    DWORD Reserved2, Reserved3;
    DWORD OutEAX, OutEBX, OutECX, OutEDX, OutEBP, OutESI, OutEDI,
    WORD  OutFS, OutGS,
    DWORD OutEFLAGS,
    } VxDParams,

/* Structure used with VxDPushCall */
typedef struct {
    DWORD CallNum,
    DWORD NumP,
    DWORD P[10],
    DWORD OutEAX, OutEDX,
    } VxDPushParams,

#define CARRYFLAG           1
#define ZEROFLAG            (1 << 6)
#define OVERFLOWFLAG        (1 << 11)

/* VxD ID assigned by vxdid@microsoft.com */
#define Generic_Dev_ID      0x28c0
/* Functions supplied by VKD.386 */
#define vKD_Version         0
#define VKD_VxDCall         1
#define vKD_VxDPushCall     3

/*
W3MAP.H is a boring file generated from w3map -verbose
#define Get_VMM_Version     0x010000L
#define Get_Cur_VM_Handle   0x010003L
#define Test_Cur_VM_Handle  0x010002L
#define Get_Sys_VM_Handle   0x010005L
#define Test_Sys_VM_Handle  0x010004L

#define Call_When_Idle      0x01003AL
#define Get_Next_VM_Handle  0x010038L
#define Set_Global_Time_Out 0x01003CL
.
etc.
*/
#include "w3map.h"   /* available on disk */

/* function calls */
typedef void (far *api_entry)(void),

api_entry GetVxDAPI(WORD vxd_id);
BOOL GenericVxDInstalled(void),
BOOL VxDCall(VxDParams far *fp);
BOOL VxDPushCall(VxDPushParams far *fp),
```

VxDCall does little more than take the VxDParams structure passed in by a function such as GetNextVMHandle and pass the structure on to INT 20h for the generic VxD entry point. VxDCall calls InitVxDAPI to initialize this entry point if necessary by calling GetVxDAPI. GetVxDAPI is just a wrapper around INT 2Fh AX=1684h. The generic VxD's ID is 28C0h. Microsoft assigns these VxD IDs.

With all the scaffolding in place, we are now ready to use the VMWALK facility to build a Windows program that examines data in DOS boxes. ENUMDRV.C, shown in Listing 3.27, this is getting rather cool! It's a Windows application that displays the Current Directory Structure (CDS) in all VMs. ENUMDRV calls vmwalk to install a walkthrough, cleverly called walkthru, which, for each VM, gets a pointer to the CDS and prints out all the drives and the current directory on each drive.

ENUMDRV uses the CURRDRIVE field from the SDA to indicate the current drive for each VM. As we know, there is a documented DOS function that returns the current drive, but calling this function returns only the current drive for the caller (that is, for the current VM). It is possible to call DOS functions in other VMs, but it is considerably easier to take this case—just grope the current VM's SDA. Note, however, that the boundschecker bug in Listing 3.4 about getting the CURRDRIVE value out of the SDA rather than calling the documented DOS function—which then just gets the value out of the SDA—maybe wasn't such a dumb idea after all.

Listing 3-27: ENUMDRV.C Displays the CDS in All VMs

```
/*
ENUMDRV.C
Version of ENUMDRV for multiple VMs in Windows Enhanced mode
Andrew Schulman, April 1993
from "Undocumented DOS", 2nd edition (Addison-Wesley, 1993)

DPMI version:
bcc -2 -DDPMI_APP -c vxdcalls.c vmwalk.c iswin.c
tlib dpmi_app+vxdcalls.obj+vmwalk.obj+iswin.obj
bcc -Z -DDPMI_APP enumdrv.c dpmi_app.lib

Windows version (uses EasyWin)
bcc -2 -W -DWINDOWS enumdrv.c prot.c vxdcalls.c vmwalk.c

WVMWALK version (uses EasyWin, no generic VxD)
bcc -W -DWINDOWS -DUSE_WVMWALK -Z enumdrv.c wvmwalk.c prot.c
*/

#include <stdlib.h>
#include <stdio.h>
#include <string.h>
#include <dos.h>

#ifdef WINDOWS
#include "windows.h"
#else
#define DPMI_APP
#include "dpmish.h"
#endif

#include "prot.h"
#ifndef USE_WVMWALK
#include "vxdcalls.h"
#endif
#include "vmwalk.h"

#define NETWORK       (1 << 15)
#define PHYSICAL      (1 << 14)
#define JOIN          (1 << 13)
#define SUBST         (1 << 12)
#define REDIR_NOT_NET (1 << 7)  /* CDROM */

typedef unsigned char BYTE;
typedef unsigned short WORD;
typedef unsigned long DWORD;
typedef BYTE far *DPB;      // provide actual DPB struct if needed

#pragma pack(1)

typedef struct {
    BYTE current_path[67];  // current path (_MAX_PATH != 67)
    WORD flags;             // NETWORK, PHYSICAL, JOIN, SUBST
    DPB  far *dpb;          // pointer to Drive Parameter Block
    union {
        struct {
            WORD start_cluster; // root  0000, never accessed  ffffh
            DWORD unknown;
            } LOCAL;        // if (! (cds[drive].flags & NETWORK))
        struct {
```

```
            DWORD redirifs_record_ptr;
            WORD parameter,
            } NET;          // if (cds[drive].flags & NETWORK)
        } u;
    WORD backslash_offset,  // offset in current_path of '\'
    // DOS4 fields for IFS
    // 7 extra bytes...
    } CDS;                  // Current Directory Structure

CDS far *curdir(unsigned drive);
void set_vm(DWORD vm);

#define ENHANCED_MODE   3

// see ISWIN.C
extern int is_win(int *pmaj, int *pmin, int *pmode);

void fail(const char *s,    )
{
    puts(s);
#ifdef DPMI_APP
    _dos_exit(1);
#else
    exit(1);
#endif
}

static void far *sysvars_real = 0;
static void far *sda_real = 0;
static int currdir_size = 0;

#ifdef DPMI_APP
// going to do initialization from real mode (real_main())
#define CALL_DOS(x,y,z)     int86x(0x21, x, y, z)
#else
#define CALL_DOS(x,y,z)     real_int86x(0x21, x, y, z)
#endif

void far *get_sysvars(void)
{
    union REGS r;
    struct SREGS s;
    memset(&r, 0, sizeof(r));
    memset(&s, 0, sizeof(s));
    r.h.ah = 0x52;
    CALL_DOS(&r, &r, &s);
    return MK_FP(s.es, r.x.bx);
}

void far *get_sda(void)
{
    union REGS r;
    struct SREGS s;
    memset(&r, 0, sizeof(r));
    memset(&s, 0, sizeof(s));
    r.x.ax = 0x5d06;
    CALL_DOS(&r, &r, &s);
    return (r.x.cflag) ? (void far *) 0 : MK_FP(s.ds, r.x.si);
}

void do_init(void)
{
#ifndef USE_NVMALK
    if (! GenericVxDInstalled())
        fail("This program requires the generic VxD (VXD.386)\n"
             "Put device=vxd.386 in [386Enh] section of SYSTEM.INI");
#endif

    // assumes SysVars at same address in all VMs
    // but CDS not necessarily at same address!
```

```
    if (! (sysvars_real = get_sysvars()))
        fail("21/52 failed: can't get SysVars\n");
    // assumes SDA at same address in all VMs
    if (! (sda_real = get_sda()))
        fail("21/5D06 failed: can't get SDA\n");
    // problem!  Microsoft C QuickWin defines _osmajor, _osminor
    // with the Windows version, not the DOS version!!
    _asm mov ax, 3000h
    _asm int 21h
    _asm mov byte ptr _osmajor, al
    currdir_size = (_osmajor >= 4) ? 0x58 : 0x51;
}
#ifdef WINDOWS
int main(int argc, char *argv[])
{
    if (! (GetWinFlags() & WF_PMODE))
        fail("This program requires Windows 3.x Enhanced mode");
    do_init();
#ifdef USE_VWMWALK
    return vwmwalk(vwalkfunc);
#else
    return vmwalk(walkfunc);
#endif
}
#else
int real_main(int argc, char *argv[])
{
    int maj, min, mode;
    puts("ENUMDRV - Enumerate CDS in all Windows VMs");
    puts("from \"Undocumented DOS\", 2nd edition (Addison-Wesley, 1993)\n");
    if ((! is_win(&maj, &min, &mode)) || (maj < 3) ||
        (mode != ENHANCED_MODE))
        fail("This program requires Windows 3.x Enhanced mode");
    do_init();  // call in real mode
    return 0;   // okay to switch into protected mode
}
int pmode_main(int argc, char *argv[])
{
    vmwalk(walkfunc);
    return 0;
}
#endif
#ifdef USE_VWMWALK
BOOL vwalkfunc(HVMD hvmd, char *title, DWORD vm, VM_CB far *vm_cb)
#else
BOOL walkfunc(DWORD vm, VM_CB far *vm_cb)
#endif
{
    CDS far *cds, far *dir;
    BYTE far *sysvars,
    BYTE far *cds_real,
    BYTE far *sda,
    DWORD total, notmapped,
    int testdrv, currdrv,
    int i,
    static DWORD sys_vm = 0;
    static DWORD cur_vm = 0;
#ifndef USE_VWMWALK
    if (! sys_vm) sys_vm = GetSysVMHandle();
    if (! cur_vm) cur_vm = GetCurVMHandle();
```

```
#endif
#define CDS_OFS         0x16
#define LASTDRV_OFS     0x21
    // Set the base address  (could also have used map_linear_vm
    // or map_real_vm. This one call to set_base will affect all
    // subsequent calls to map_linear.
    set_base(vm_cb->CB_High_Linear);
    sysvars = (BYTE far *) map_real(sysvars_real, LASTDRV_OFS+1);
    // Note  does _not_ assume that CDS at same address in all VMs!
    // But moving a CDS breaks in Windows anyway, because DOSMGR assumes
    // that CDS never moves after Windows initialization. *Sigh*
    cds_real = * (BYTE far * far *) &sysvars[CDS_OFS];
    lastdrv = sysvars[LASTDRV_OFS];
    free_mapped_linear(sysvars);
    printf("\n%s (VM %lu) -- CDS at %DBLK\n",
        (vm == sys_vm) ? "System VM"
        (vm == cur_vm) ? "Current VM"
        /* default */    "DOS Box ",
        vm_cb->CB_VMID,
        vm_cb->CB_High_Linear + MK_LIN(cds_real));
#define CURRDRV_OFS     0x16
    // get current drive for this VM from SDA:0016
    // for System VM, will depend on current task
    // (each Windows app has its own current drive/directory)
    // already did set_base vm_cb->CB_High_Linear),
    sda   (BYTE far *) map_real(sda_real, CURRDRV_OFS+1),
    currdrv   sda[CURRDRV_OFS],
    free_mapped_linear(sda),
    //  map in cds_real for this VM, print out, free it
    cds   (CDS far *) map_real(cds_real, lastdrv * currdir_size),
    for (i 0, i<lastdrv, i++)
    {
        dir = (CDS far *) (((BYTE far *) cds) + (i * currdir_size)),
        if (dir->flags)
        {
            // highlight current drive for this VM
            printf( (i == currdrv) ? "==> " : "    " );
            printf("%c:\t%Fs", 'A' + i, dir->current_path);
            if (dir->flags & REDIR_NOT_NET) printf( REDIR_NOT_NET  );
            else if (dir->flags & NETWORK) printf("NETWORK  "),
            if (dir->flags & JOIN) printf("JOIN "),
            if (dir->flags & SUBST) printf("SUBST");
            printf( \n ),
        }
    }
    free_mapped_linear(cds),
    set_base(0);   // restore
    return TRUE;
}
```

Figure 3-8 shows output from ENUMDRV. By looking at all the VMs this program provides a telling demonstration that Windows must take multiple current drives and directories by instancing the CDS. The CDS is at the same segment:offset address in each VM, though ENUMDRV does not in fact depend on this. But of course that's not sufficient. It is worth contrasting this with, for example, the SFT, which is not instanced aside from the link to the PSP VII exe and Grow SFT segments, discussed earlier.

Figure 3-8: ENUMDRV Shows the CDS in Each Windows VM

```
System VM (VM 1) -- CDS at 81410D80
    A   A:\
```

```
    B   B:\
==> C   C:\SICE
    D   D:\
    E   E:\
    F   F:\
    G   G:\
Current VM (VM 2, ~= COS at B1B1C0B0
    A   A:\
    B   B:\
==> C   C:\UNDOC2\CHAP3
    D   D:\
    E   E:\
    F   F:\
    G   G:\
```

If you look at ENUMDRV.C, you will notice that you can use it to build a DPMI .EXP, a Windows application using EasyWin or QuickWin, or a Windows application with something called WVMWALK. However, we cannot call this example VMJ ENUMDRV as a real-mode DOS program because, as a real-mode program, you cannot call the generic VxD to enumerate VM handles the program needs a flat address space to access them.

What is WVMWALK.C? It's a hack that a Windows application can bypass the generic VxD entirely and use an old Windows 3.0 interface to enumerate VM handles. Remember, we're using the generic VxD just to get a few VM handles. Everything else, such as getting the VM handle into a usable VM CB structure and then using the high linear field stored away using the MapLinear() function provided by PROTECT.

The extremely nice thing about this hack is that it's possible to enumerate DOS boxes from a Windows program. WINSPY.C showed how to walk the Windows task list and detect the IsWinOldApTask(). You can also easily walk the window list using GetWindow() and the task list each window belongs to (GetWindowTask() and IsWinOldApTask()) to enumerate DOS boxes. David Jones of the *Windows DOS Developer's Journal* and Matt Pietrek of Microsoft found a hack in Windows 3.1 called DEC that uses a DOS device driver that hooks the DOS device VM and sends *Window DOS Developer's Journal* (WDJ). This makes it possible to write a VM ENUMERATOR that can use the Windows standard facility to enumerate VM handles.

The resulting code, WVMWALK.C, is shown in Listing 3.28. Of course, this code is totally dependent on the VM data structure. Most likely it won't work on any version of Windows other than 3.1. You can run the WVMWALK.EXE ENUMDRV to form a Windows version of ENUMDRV that doesn't require the generic VxD; see the instructions at the top of Listing 3.28.

Listing 3.28. WVMWALK.C, a Slimy Hack to Enumerate VM Handles from Windows

```
/*
WVMWALK.C -- Version of VMWALK for Windows 3.1
Andrew Schulman, April 1993
From "Undocumented DOS", 2nd edition (Addison-Wesley, 1993)
*/

#include <stdlib.h>
#include <string.h>
#include <dos.h>
#include "windows.h"
#include "protect.h"
#include "vmwalk.h"

// see WDDJ, December 1992 (this is Paul Bonneau's doing!)
// see also MSJ, February 1993, p. 30
#define VM_FROM_HWND(hWndDosBox) \
    *((LPDWORD) MK_FP GetWindowWord(hWndDosBox, GWW_HINSTANCE), 0x0FC))

// since undoc, missing from some import libs, so do run-time link
static BOOL (FAR PASCAL *IsWinOldApTask)(HANDLE hTask) = 0;
```

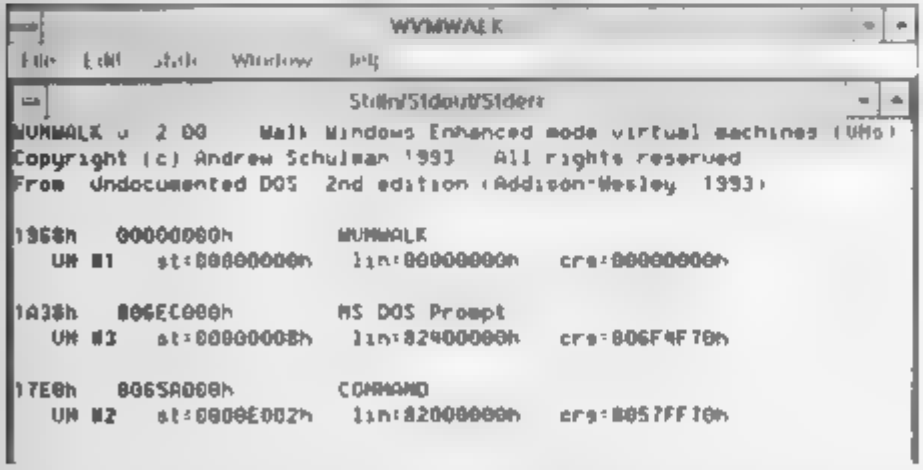
```
// from Undocumented Windows, p. ___
BOOL IsDosBox(HWND hWnd)
{
    if (! IsWinOldApTask) // one-time init
        if (! (IsWinOldApTask = (BOOL (FAR PASCAL *)(HANDLE))
            GetProcAddress(GetModuleHandle("KERNEL"),"ISWINOLDAPTASK")))
                fail("Can't find KERNEL IsWinOldApTask");
    return (*IsWinOldApTask)(GetWindowTask(hWnd));
}

typedef BOOL (*WWALKFUNC)(HWND hwnd, char *title, DWORD vm, VM_CB far *vm_cb);

int vmwalk(WWALKFUNC walkfunc)
{
    char buf[0x50],
    VM_CB dummy,
    HWND hwnd,
    int num_vm,

    if ((WORD) GetVersion()) != 0x0A03)
        return 0;       // only works in Windows 3.1
    if (! (GetWinFlags() & WF_ENHANCED))
        return 0;       // only works in Enhanced mode

    hwnd = GetActiveWindow(),
    GetWindowText(hwnd, buf, 0x50),

    // Can't get handle for System VM, but that is VM the Windows
    // app is running in! So make a dummy VM_CB and pass that
    // (actually, COULD get System VM by walking VM next ptrs):
    memset &dummy, 0, sizeof(dummy));
    dummy.CB_High_Linear = 0;   // current VM
    dummy.CB_VMID   1,          // System VM is always VM 1
    if (! (*walkfunc)(hwnd, buf, 0, &dummy))
        return 0,
    num_vm = 1;

    hwnd = GetWindow(hwnd, GW_HWNDFIRST),
    while (hwnd)
    {
        if (IsDosBox(hwnd) && GetWindowText(hwnd, buf, 0x50))
        {
            DWORD vm = VM_FROM_HWND(hwnd),
            VM_CB far *vm_cb   (VM_CB far *)
                map_linear(vm, sizeof(VM_CB)),
            VM_CB my_vm_cb,
            _fmemcpy(&my_vm_cb, vm_cb, sizeof(VM_CB)),
            free_mapped_linear(vm_cb),
            if (! (*walkfunc)(hwnd, buf, vm, &my_vm_cb))
                return num_vm,
            set_base(0);  // in case app changed base
        }

        hwnd = GetWindow(hwnd, GW_HWNDNEXT),
    }
    return num_vm,
}

#ifdef TESTING
#include <stdio.h>

BOOL wwalkfunc(HWND hwnd, char *title, DWORD vm, VM_CB far *vm_cb)
{
    printf( "%04Xh\t%08lXh\t\"%s\"\n", hwnd, vm, title);
    printf(    VM #%i,u   st=%08lXh   lin=%08lXh   crs=%08lXh\n\n",
        vm_cb->CB_VMID,
        vm_cb->CB_VM_Status,
        vm_cb->CB_High_Linear,
        vm_cb->CB_Client_Pointer);
```

```
    return 1;
}
main()
{
    return uvmwalk(vwalkfunc);
}
#endif
```

Aside from its extreme version dependence, there is a problem with WVMWALK. It does not get a handle for the System VM. However, this is not a major problem. This technique only works for Windows applications, not Windows apps can assume the System VM ID is one, since a Windows application runs in a WVMWALK version of ENUMDRV is running as the System VM, the current VM, so the program knows it must be high memory addresses anyway. It can access an LDT or whatever with a base of zero, just as we did a long time ago. Now, we don't know about VM handles, high base addresses, and other details. WVMWALK accesses some VMCB data for the System VM. Little more. By using the next pointer stored at offset 68h in each VMCB, we can walk the VM linked list in memory. It is possible to locate the System VM, which is VM ID #1.

Actually, you could obtain such information via VMCB ROM DRIVER technique, but not with the generic VxD. In Figure 3-8, it would be nice to have some more identification for each VM, such as its window title. Meanwhile, the WVMWALK version, since it starts with a window handle, is able to display window titles (see Figure 3-9). You could combine the two techniques to produce a single, more useful display. After all, most users don't think of VMs or even of DOS boxes; they think of the applications they are running.

Figure 3-9: WVMWALK Version of ENUMDRV



Note finally that ENUMDRV can also be built as a DPMI APP. There is a twist here, however. We earlier built several utilities that required DPMI, and these could actually run not only in Windows but under any DPMI host, such as 386MAX or QEMM. With ENUMDRV, though, we have a DOS program that uses some VMM/WVMWALK and VxD API calls that does require Windows Enhanced mode. ENUMDRV uses the function in WIN386.EXE to ensure that it is running under Enhanced mode. Listing 3-29 shows ISWIN.C.

Listing 3-29: ISWIN.C: DOS Code to Check for Windows

```
/*
ISWIN.C
Detecting Windows mode, version from DOS
Andrew Schulman, February 1993
bcc  DSTANDALONE iswin.c
*/

#include <stdlib.h>
#include <stdio.h>
#include <dos.h>

#define REAL_MODE           1
#define STANDARD_MODE       2
#define ENHANCED_MODE       3

#define SYSTEM_VM           1

int detect_switcher(void)
{
    int retval = 1;
    _asm push di
    _asm push es
    _asm xor bx, bx
    _asm mov di, bx
    _asm mov es, bx
     asm mov ax, 4b02h
    _asm int 2fh
    _asm mov cx, es
     asm or cx, di
    _asm je no_switcher
done:
    _asm pop es
    _asm pop di
    return retval;
no_switcher:
    retval = 0;
    goto done;
}
// a lot more complicated than you would have thought!
int is_win(int *pmaj, int *pmin, int *pmode)
{
    unsigned short retval;
    int maj=0, min=0, mode=0;

    /* make sure someone, anyone has INT 2fh */
    if (_dos_getvect(0x2f) == 0)
        return 0;

    /* call 2F/160A to see if Windows 3.1+ */
    _asm mov ax, 160ah
    _asm int 2fh
     asm mov retval, ax
    if (retval    0)                /* AX=0 if Windows running */
    {
        _asm mov mode, cx            /* CX=2 means Std; CX=3 means Enh */
        _asm mov byte ptr maj, bh    /* BX = major/minor (e.g., 030Ah) */
        _asm mov byte ptr min, bl
        *pmaj = maj;
        *pmin = min;
        *pmode = mode;
        return 1;
    }

    /* call 2F/1600 to see if Windows 3.0 Enhanced mode or Windows/386 */
    _asm mov ax, 1600h
     asm int 2fh
    _asm mov byte ptr maj, al
```

```
    _asm mov byte ptr min, ah
    if ((maj == 1) || (maj == 0xFF))    /* Windows/386 2.x is running */
    {
        *pmaj = 2;                  /* Windows/386 2.x */
        *pmin = 1;                  /* don't know; assume 2.1? */
        *pmode = ENHANCED_MODE, /* Windows/386 sort of like Enhanced */
        return 1;
    }
    else if (! ((maj==0) || (maj==0x80))) // AL=0 or 80h if no Windows
    {   /* must be Windows 3.0 Enhanced mode */
        *pmaj = maj,
        *pmin = min,
        *pmode = ENHANCED_MODE;
        return 1;
    }
    /* call 2F/4680 to see if Windows 3.0 Standard or Real mode, but,
       this could be a "3.0 derivative" such as DOSSHELL task switcher! */
    _asm mov ax, 4680h
    _asm int 2fh
    _asm mov retval, ax
    if (retval == 0)                /* AX=0 if 2F/4680 handled */
    {
        /* make sure it isn't DOSSHELL task switcher */
        if (detect_switcher())
            return 0;
        *pmaj = 3;
        *pmin = 0;
        /* either have Windows Standard mode or Real mode; to
           distinguish, have to do fake Windows broadcasts with
           2F/1605  Yuk! We'll avoid that here by assuming
           3.0 Standard mode.  If you really want to distinguish
           3.0 Standard mode and Real mode, see _MSJ_, March 1991,
           p. 113, and MS KB articles Q75943 and Q75338 */
        *pmode = STANDARD_MODE;
        return 1;
    }
    /* still here -- must not be running Windows */
    return 0;
}
#ifdef STANDALONE
main()
{
    int maj, min, mode=0;
    if (! is_win(&maj, &min, &mode))
        printf("Windows is not running\n");
    else if (maj == 2)
        printf( Running Windows/386 2.x\n ),
    else
        printf("Running Windows %u %02u (or higher) %s mode\n",
            maj,
            min,
            (mode == REAL_MODE) ?     "Real" :
            (mode == STANDARD_MODE) ? "Standard" :
            (mode    ENHANCED_MODE) ? "Enhanced" :
            /* don't know */ "???");
    if (mode == ENHANCED_MODE)
    {
        unsigned short vm;
        /* call 2F/1683 to see if DOS app running in System VM; if so,
           this must be some hacked version of Windows like MSDPM1,
           or we must be running inside WINSTART.BAT */
        _asm mov ax, 1683h
        _asm int 2fh
```

```
        _asm mov vm, bx
        if (vm == SYSTEM_VM)
            printf("Running DOS app in System VM\n"
                   "Must be WINSTART.BAT or hacked-Windows\n");
        else
            printf("VM #%u\n", vm);
    }
     * could also call 2F/160C to check for Windows in ROM */
    return mode;    /* can be tested with ERRORLEVEL */
}
#end 1
```

Something as seemingly simple as checking for Windows turns out to be so complicated that it requires 150 lines of code!

Undocumented DOS and DesqView

by Ralf Brown

With all this talk about Windows, what about other multitasking windowing environments for DOS, such as Quarterdeck's DESQview?

Although no special preparations are required to access undocumented DOS functions or data from a program running under the DESQview multitasker, task switching should be disabled when modifying DOS data structures through any method other than INT 21h calls.

DESQview serializes access to DOS via INT 21h, thus automatically avoiding problems with DOS data structure modifications. If a program directly modifies DOS internal data, however, a task switch could occur while the data is being modified. Ordinarily, one could just disable interrupts while making the modifications, but this will not work on 386 and higher processors. QEMM, used in DESQview 386, and other memory managers virtualize the interrupt flag, with the result that DESQview is able to task switch even while interrupts appear to be disabled. Therefore, task switching must be explicitly disabled by asserting a critical sector using TopView API calls. While IBM's TopView has gone to the land of the cut-out bins (you can purchase TopView for $4.95 at a store called Weird Stuff in Sunnyvale, CA; a TopView SDK there costs $7.95), its API still lives on in DESQview, as well as in Sunny Hill Software's TaskView OmniView.

Listing 3.30: DESQVIEW.C (Actually, More Like TopView)

```
static int TopView = 0 ;

void check_TopView(void)
{
   union REGS regs ,
   regs.x.ax = 0x1022 ;          /* get TopView version */
   regs.x.bx = 0 ;
   int86(0x15,&regs,&regs) ,
   TopView = regs.x.bx ,         /* nonzero if TopView or compatible */
}

void TopView_begincrit(void)
{
   union REGS regs ,
   if (TopView)
   {
      regs.x.ax = 0x1018 ;          /* start critical section */
      int86 0x15,&regs,&regs) ,
   }
}
```

```
void TopView_endcrit(void)
{
   union REGS regs ;
   if (TopView)
   {
      regs.x.ax = 0x101C ;          /* end critical section */
      int86(0x15,&regs,&regs) ;
   }
}
```

These three functions are used in the following manner: call check_TopView() once near the beginning of the program to initialize the TopView variable. Then, each time a DOS data structure is to be modified, surround the code performing the modification by calls to TopView_begincrit() and TopView_endcrit(), which disable and enable task switching, respectively.

This chapter's discussion of Windows-hosted entries to *In Boot* at DOS internal data structures, so the question of critical sections never came up. However, Raff's point about *modifying* structures in DESQview actually applies with equal force to Windows. A second where a DOS box's Background execution might access a program that modifies DOS internal data should use the Begin Critical Section (INT 2Fh AX=1680h) and End Critical Section (INT 2Fh AX=1681h) calls which the Windows DDK documents. Do not overlook a useful Microsoft knowledge base article, "Using the Interrupt 2F Critical Section Services" (Q78151) notes that despite their name these functions "do not provide a true switch-safe mechanism" and support task switching only in a limited way. Sheesh! It's considerably more valuable that a sequence of code not be interrupted and switched away from, you need to put the code in a VxD.

A Brief Introduction to VxD Programming

Speaking of VxDs, as we've seen we have VxD code fragments both here and in Chapter 1, but we really need a book or two to complete a discussion of writing VxDs.

UNDOSMGR.ASM, listing 3-31, is the 32-bit assembler language source code for UNDOSMGR.386, a virtual device driver that provides *ring-2 support* to protected mode code in a single-tasking, non-DOS box, DOS 5+ session. INT 2Fh AX=1606h (Get NTVDM Task ID) tells us this. Later we saw how a program running under Windows can use DPMI to call DOS functions from protected mode. Recall that to use DPMI to access the function that Windows supports, of course, non-transparent.

However, if a VxDOSMGR.386 is installed, certain DOS calls such as Novell's undoc2.exe/up3 undosmgr.386 (or even 386load undosmgr.386 in system.ini) and INT 2Fh AX=1606h are supported in protected mode and protected mode programs no longer have to access via DPMI. They can just call DOS functions as they would in real mode, and the UNDOSMGR VxD takes care of everything. With UNDOSMGR installed, a straight protected mode port of C:\RRDRIV.C (listing 3-30) works properly and loads DOS device drivers. No longer generates error messages from the debugging version of UNDOSMGR.

Listing 3-31: UNDOSMGR.ASM

```
; UNDOCMGR.ASM
; Sample VxD that provides one undocumented DOS function (21/5D06)
;       in protected mode
; Andrew Schulman, April 1993
; from  Undocumented DOS , 2nd edition (Addison-Wesley, 1993)
.386p

INCLUDE VMM.INC
INCLUDE V86MMGR.INC
```

```
;******************************************************************************
;       V I R T U A L   D E V I C E   D E C L A R A T I O N
;******************************************************************************
Declare_Virtual_Device UNDOSMGR, 1, 0, \
    Control_Proc, \
    Undefined_Device_ID, \
    Undefined_Init_Order, , ,\
;******************************************************************************
;               O N L Y   D A T A   S E G M E N T
;******************************************************************************
VxD DATA SEG

Prev_Int21Pmode     dd  0
Prev_Int21Pmode_Seg dw  0

VxD DATA ENDS
;******************************************************************************
;          M O V E A B L E   C O D E   S E G M E N T
;******************************************************************************
VxD_CODE_SEG

BeginProc   Int21Pmode
    mov     eax, [ebp.Client_EAX]
    cmp     ax, 5D06h
    je      short Do_GetSDA

Default:
    movzx   ecx, Prev_Int21Pmode_Seg    ;; "NOT" mov cx"
    mov     edx, Prev_Int21Pmode
    VMMcall Simulate_Far_Jmp
    jmp     short Fini

Do_GetSDA:
IFDEF BYPASS_V86MMGR
    ; Sample code to show how this looks with raw VMM calls
    VMMcall Simulate_Iret
    VMMcall Begin_Nest_V86_Exec
    mov     eax, 21h
    VMMcall Exec_Int                    ; reflect INT 21h to V86 mode
    VMMcall Resume_Exec                 ; do it now!
    movzx   eax, [ebp.Client_DS]        ; get V86 DS inside nest
    VMMcall End_Nest_Exec
    shl     eax, 4                      ; make linear address
    mov     ecx, 0FFFFh                 ; 64k segment
    VMMcall Map_Lin_To_VM_Addr          ; create permanent selector
    mov     [ebp.Client_DS], cx         ; return selector to caller in DS
ELSE
    VMMcall Simulate_Iret
    mov     edx, OFFSET32 GetSDA_API
    VxDcall V86MMGR_Xlat_API
ENDIF

Fini:
    clc
    ret

GetSDA_API:
    Xlat_API_Return_Ptr DS, SI
    Xlat_API_Exec_Int 21h
EndProc     Int21Pmode

VxD_CODE_ENDS
;******************************************************************************
;          L O C K E D   C O D E   S E G M E N T
;******************************************************************************
VxD LOCKED CODE SEG

BeginProc   Control_Proc
```

```
    Control_Dispatch Device_Init, Do_Device_Init
    clc
    ret
EndProc     Control_Proc

VxD_LOCKED_CODE_ENDS

;******************************************************************************
;               P M   I N I T   C O D E   S E G M E N T
;******************************************************************************
VxD_ICODE_SEG

BeginProc   Do_Device_Init
    ; get previous pmode INT 21h handler, so can chain
    mov     eax, 21h
    VMMcall Get_PM_Int_Vector
    mov     Prev_Int21Pmode, edx        ; offset
    mov     Prev_Int21Pmode_Seg, cx     ; segment

    ; turn Int21 handler into pmode callback
    xor     edx, edx
    mov     esi, OFFSET32 Int21Pmode
    VMMcall Allocate_PM_Call_Back
    jc      short Done
    ; segment:offset callback address in EAX

    ; install pmode Int21 handler
    mov     ecx, eax
    movzx   edx, ax
    shr     ecx, 10h
    mov     eax, 21h            ; eax = intno
    VMMcall Set_PM_Int_Vector
Done:
    ret
EndProc     Do_Device_Init

VxD_ICODE_ENDS

;******************************************************************************
;               R E A L   M O D E   I N I T I A L I Z A T I O N
;******************************************************************************
VXD_REAL_INIT_SEG

; just a stub real_init procedure
real_init proc near
    xor ax, ax
    xor bx, bx
    xor si, si
    xor edx, edx
    ret
real_init endp

VXD_REAL_INIT ENDS
    END
```

VxDs are 32-bit linear executable EXE files whose the standard Microsoft assembler and linker currently can't build. To create UNDOSMGR.ASM into UNDOSMGR.386 you will need Microsoft's MASM5 LINK386 and ADDHDR utilities and Microsoft's all important VMM.INC header file, included with the Windows DDK and with the "VxD Tool" package available on the MSDN CD-ROM. MK.VXD is a batch batch file for making simple VxDs:

```
rem MK_VXD.BAT
set include=\ddk\inc\vxd
masm5 -p -w2 %2 %1,
link386 %1,%1.386,,,%1.def
addhdr %1.386
```

For example, MK_VXD UNDOSMGR or MK_VXD UNDOSMGR DBYPASS V86MMGR. See below for an explanation of BYPASS V86MMGR. You will also need UNDOSMGR.DEF, provided on the accompanying disk.

How does UNDOSMGR work? The Declare Virtual Device statement near the top of UNDOSMGR.ASM establishes the function Control_Proc as UNDOSMGR's event handler. Control_Proc, further down in UNDOSMGR.ASM, is interested in only one event, Device_Init. Control_Proc establishes the Do_Device_Init function as the handler for the Device_Init event. Do_Device_Init patches UNDOSMGR into the protected mode INT 21h handler chain. It calls the VMM function Get_PM_Int_Vector to retrieve the previous handler's address and calls Set_PM_Int_Vector to install the UNDOSMGR handler. This handler, called Int21Pmode, is at code segment 0028h. Recall that segment numbers differ from normal in protected mode. So that programs running under Windows, UNDOSMGR passes the address of Int21Pmode to the VMM Allocate_PM_Call_Back function and returns a protected mode "callback" that can be called from normal programs. By passing back a pointer to this callback to Set_PM_Int_Vector, UNDOSMGR guarantees that every time any program running in protected mode (Windows or not) issues an INT 21h, the call will go to UNDOSMGR's Int21Pmode handler.

That's the end of UNDOSMGR's initialization. Now it lies dormant, its Int21Pmode handler waiting for protected mode INT 21h calls. Each time it's called, Int21Pmode checks to see if the application has issued INT 21h AX=5D06h. This DOS undocumented function, called by the opening gambit of Quick C 2.0's DOS.C library, requests a pointer to the DOS swappable data area (SDA). Int21Pmode chains to the previous INT 21h handler and then issues its own INT 21h function 5D06h. I got this trick from the DOS/4GW DOS Extender sample source code for chaining protected mode interrupts.

The next call to Int21Pmode will find that the application has issued an INT 21h AX=5D06h in protected mode. UNDOSMGR.ASM has two ways of handling this call. If assembled with /DBYPASS_V86MMGR, UNDOSMGR.ASM has its own version of the VMM calls. It's very similar to those we saw back in Chapter 5's DPMI program, with the exception of UNDOSMGR. UNDOSMGR contains code that is nearly identical to that in DOSMGR and in fact, even uses DOSMGR's own Easy Segment Allocation API. If assembled without the BYPASS_V86MMGR switch, UNDOSMGR uses the V86MMGR Mini API, which is a collection of calls to the DPMI API wrapped in the V86MMGR Mini API function. Either way, UNDOSMGR calls its INT 21h Int21Pmode V86 code and data transfers DS into a protected mode selector using the V86 API. Recall that V86MMGR or Map_Flat_To_VM_Addr with direct VMM calls.

Timing DOS Calls

Clearly, VxDs provide a lot of power to extend the Windows DOS extender and provide direct system services. VxD programming in many ways is to DOS systems programming in the 1990s what TSRs were to DOS programming in the 1980s. But it's not all sweetness and light. INT 21h calls issued from protected mode INT 21h handlers, such as UNDOSMGR's Int21Pmode function, execute very slowly. UNDOSMGR's own initialization code issues an INT 21h AX=5D06h. We can measure the impact of UNDOSMGR and the slowness of protected mode VMM VxD mechanisms with a special DPMI program, DOSSPEED.C, which simply issues a large number of very simple INT 21h calls. DOSSPEED runs this DOS call loop once, then again in V86 mode, then switches to protected mode and runs the loop again. It displays the number of seconds each run takes. Listing 3-32 shows DOSSPEED.C.

Listing 3-32: DOSSPEED.C

```
/*
DOSSPEED.C -- time DOS operations
Andrew Schulman, May 1993
From "Undocumented DOS", 2nd edition (Addison-Wesley, 1993)
bcc -DDPMI APP -2 dosspeed c dpmi_app.lib
*/
```

```
#include <stdlib.h>
#include <stdio.h>
#include <dos.h>
#include <time.h>
#include "dpmish.h"

void dosspeed(unsigned long iter)
{
    time_t t1, t2;
    unsigned long i;

    time(&t1);
    for (i=0; i<iter; i++)
    {
        _asm mov ah, 2Ah            /* get date */
        _asm int 21h
        _asm mov ah, 2Ch            /* get time */
        _asm int 21h
        _asm mov ah, 51h            /* get PSP */
        _asm int 21h
        _asm mov ax, 3000h          /* get version */
        _asm int 21h
    }
    time(&t2);
    printf("%lu calls in %lu seconds\n", iter * 4, t2 - t1);
}

void fail(const char *s, ...) { puts(s); _dos_exit(1); }

int real_main(int argc, char *argv[])
{
    printf("real mode: ");
    dosspeed((argc < 2) ? 10000 : atol(argv[1]));
    return 0;
}

int pmode_main(int argc, char *argv[])
{
    printf("prot mode: ");
    dosspeed((argc < 2) ? 10000 : atol(argv[1]));
    return 0;
}
```

On a standard 80386SX 20 laptop DOSSPEED turned in the following times for 10,000 sets of the four calls INT 21h AH 2Ah AH 2Ch AH 30h and AX 3000h (see the earlier discussion that these four functions are typically called very frequently):

MS-DOS 5 (no memory manager)	5 seconds
MS-DOS 5 (386MAX or EMM386)	8 sec
MS-DOS 5 (Windows Enhanced mode DOS box)	13 sec
386MAX DPMI client	23 sec
Windows Enhanced mode DPMI client	26 sec
W Enh mode, with UNDOSMGR 386 installed	29 sec
Novell DOS 7 with KRNL386.SYS	20+ sec
Novell DOS 7, in DPMI	50+ sec

As with any hastily concocted benchmark, one can conclude from these figures whatever one wants. However, it does seem clear first that there is a small but noticeable overhead for installing VxDs that hook frequently used software interrupts and that more importantly there is a large and very noticeable workload for running a V86 mode under Windows Enhanced mode and in even larger and more noticeable overhead for making DOS calls from protected mode. As a fitting conclusion to this chapter on porting DOS programs to protected mode, perhaps DOSSPEED is trying to tell us that as long as Windows has to call down to real mode DOS, the best way to make a lot of DOS calls from protected mode is not to make them at all.

CHAPTER 4

Other DOSs: From DR DOS and NetWare to MVDMs in OS/2 and Windows NT

For better or worse, the MS-DOS INT 21h programming interface has become a worldwide computing standard. Even though the system was best programming language suited to C or C++ as standards, there is no committee to oversee the DOS standard. It is a proprietary standard controlled by Microsoft, but many other companies have implemented the DOS interface. DOS-compatible software now runs on many operating systems besides MS-DOS, including OS/2, NT, DOS, 2, and Microsoft's own Windows NT.

The same thing is starting to happen with Windows. Accessible software now runs under several UNIX environments such as X Windows Application Binary Interface (XABI) from SCO, Microsoft's OpenServer, and Open Desktop's Portable Windows Environment. In fact, Sun's promised open-standard Solaris Windows interface (PWI) is based on Windows 3.1 under the patent-free domain. *Dr Dobb's Journal* (Vol. 19, No. 4, April 1994, pp. 44–54) describes a port of Portable IBM Quarterdeck WordPerfect and other Windows software to X Windows. Because Windows PWI ideally should be compatible with DOS and Windows device drivers, it should be easier to port DOS and Windows software than to port software that runs only under UNIX standards.

Even when DOS is not the native operating system, it is likely that the underlying DOS system will always be Microsoft's MS-DOS. In order to succeed, competitors such as Digital Research, Novell, Software Link, and others have had to provide DOS-compatible systems. Digital Research's DR DOS, Novell's NetWare Lite, and Novell's Personal NetWare are all DR DOS descendants. DR DOS originated in the CP/M operating system and was later ported to MS-DOS. Digital Research's DR DOS was a competitor to MS-DOS until DR DOS was sold to Novell. Novell DOS 7 is the current version of DR DOS. Novell DOS 7 is the only DOS that comes with a network. Given the continuing dominance of Novell's NetWare, the Novell operating system is the most widely used DOS. Novell DOS 7 provides nearly all the features of Microsoft's MS-DOS.

What does it mean to be DOS-compatible? It means that you know that you can just run out Microsoft's *MS-DOS* programs better, faster, and cheaper. Each vendor has produced its own set of enhancements to DOS. Novell DOS 7 has added many of the most popular DOS application services. Looking past the INT 21h services, you would have to research the exact support function 52h. And this would require a specific task, such as to get the SysVars (List of Lists) structure. If you wanted to run as a network redirector, you would have to implement the DOS side of the network redirector interface (INT 2Fh AH=11h, see Chapter 8). And if you wanted Windows and thereby run WinWord and Excel, you would have to create a Swappable Data Area and to know $1000h plus additional other stuff that should be implementation details, but which are part of the *de facto* DOS specification.

In implementing a version of DOS, a company might have some good ideas about how to implement different data structures. Tough luck. You had better have an MS-DOS style Current Directory Structure for the drive directory tracks, a System File Table for open files, Memory Control Blocks, and so on. At least you need copies of them—enough to keep different applications happy—and then some mechanism for translating state from these dummy DOS structures to whatever internal structures your system actually uses.

The worst of it is, we're creating a DOS workalike, you would need to keep a number of supposedly private variables at certain fixed locations in your DOS's data segment. For example, later in this chapter we'll see that some Microsoft C compilers depend on the presence of a flag at offset 4 in the DOS data segment and expect the current PSP to be stored in the same segment at either offset 210Eh or 330h (see listing 4-4).

What all the most successful DOS applications and DOS users want is wide. The DOS specification, if such exists, is the applications themselves. Any self-respecting DOS workalike must, by definition, support whatever the popular PC applications do.

This problem of implementation-dependent, undocumented system specification requirements is not unique to DOS. Various people have worked in the computer parallel to business trying to get applications from one environment to run in another. But even now, no one knows how you go about such emulation. You take the real application and run it on your new system and see if it runs. When the application bombs or doesn't do anything good, you make some change or addition to your operating system. In specification, most of what you're doing is collected from the applications. You see what the applications expect of their environment, and you provide it.

In Fred Brooks's book of essays on software engineering, *The Mythical Man Month*, Fred Brooks has a good discussion of compatibility and *de facto* standards:

> An important instance arose as a hardware decision. When the first compatible computers were built, it was decided that the new machine was to match an existing machine's behavior in all of its externally visible characteristics, including bugs. The goal was to run all programs developed for the old machine, including system programs, on the new machine with no changes. Only thus could the new machine's customers be assured that their huge software investments were secure.
>
> Unfortunately, this goal proved to have some serious disadvantages. All questions can be settled by experiment. Behavior is completely specified. Answers are always available. Programs can be run to see what they do. The decision is by definition correct. Opposed to these overwhelming advantages is the single disadvantage that the implementation may over-prescribe even the externals. Even in a perfect system, all kinds of side effects may appear, and these will have to be preserved by programmers. When we undertook to emulate the IBM 1401 on System/360, for example, I discovered that there were 30 different "curious" side effects that supposedly no decent programs ever depended on, that had come into widespread use, and had to be considered as part of the definition.
>
> *Real* errors in documentation will often be found to be inadequate as these particulars prove important. Because the system is complex, the errors will often turn out to be obscure, not to be found by casual testing, and not to be duplicated on demand. For example, some machines have a short-cut multiply that is faster after a multiplication. The precise nature of this trash is important to part of the definition, yet duplicating it may preclude the use of a faster multiplication algorithm.

In this chapter we look at the work of several companies engaged in the game of DOS compatibility. These companies must get to know and then reimplement the different "curious" one might even say *undocumented*—DOS idiosyncrasies. Novell DOS, formerly DR DOS, must of course be as close as possible to MS-DOS while providing additional features at a lower cost. In this chapter, we see how close Novell DOS comes to this goal.

Novell NetWare is not a clone of DOS, but as we already saw briefly in Chapter 2, it hooks DOS and makes some important alterations to it. We discuss NetWare in more detail while we discuss

Novell DOS makes sense. In fact, we'll see that Novell NetWare makes so many changes to the INT 21h interface that, even though it seems to run "on top of" DOS, it effectively replaces DOS and thereby fully qualifies as an "other DOS."

IBM OS/2 2.x and Windows NT most definitely do not hook or in any other way sit on top of DOS; they completely replace it. But market reality dictates that these environments run DOS programs out of the box. This ability is called *binary compatibility*, in contrast to the much simpler goal of source compatibility. In fact, users may for some time, perhaps, such environments primarily for the purpose of running old DOS or Windows software. This requires that the new operating system either emulate DOS or run a copy of genuine DOS within a virtual machine. Either way, an important question is whether DOS programs that access undocumented DOS data structures and call undocumented DOS functions will run in these environments. Undocumented DOS is an excellent test of DOS compatibility. Achieving compatibility with documented interfaces is fairly easy, so when you hear discussions of "DOS compatibility" or "Windows compatibility," it's really support for the undocumented interfaces that's being discussed.

An interesting point emerges from all this: It is often a Microsoft rival, or other major applications (not necessarily or even primarily its own), to use undocumented DOS features, as this ties those applications to Microsoft's own versions of DOS, more especially than IBM's license to the DOS source code runs out in September 1993. After all, what's the main difference between Microsoft's DOS and anyone else's, except that Microsoft has guaranteed better support for the things undocumented things that DOS applications do? For Microsoft, undocumented DOS is thus an interesting form of product differentiation.

From CP/M to DR DOS to Novell DOS

The funny thing is, MS-DOS itself started out as a clone of the CP/M operating system from DRI. The story has been told many times of how Tim Paterson, a contributor to the first edition of this book, now at Microsoft, but in 1980 an employee at Seattle Computer Products, wrote what was Quick and Dirty DOS (QDOS), later 86-DOS, to which Microsoft purchased non-exclusive rights, and how this became MS-DOS 1.0 for the then new IBM PC. Stephen Manes and Paul Andrews' history of Microsoft, *Gates*, has the rather curious photocopy of the original Seattle Computer order form for Microsoft's purchase of 86-DOS, showing its price: $50,000.

Quick, dirty, and cheap. As Andrew Tanenbaum notes in his superb textbook on *Modern Operating Systems*: "If anyone had realized that within 10 years this tiny system that was picked up almost by accident was going to be controlling 50 million computers, considerably more thought might have gone into it."

Somewhat understandably, Digital Research was upset when it found that Microsoft's new operating system for the IBM PC was a clone of CP/M. Apparently, Digital's Gary Kildall even considered suing IBM over the similarity of MS-DOS to CP/M. Microsoft would be similarly upset today if someone came out with a graphical environment that happened to provide the same API as Windows.

There's no question about MS-DOS's large-scale borrowing from CP/M. As Tim Paterson would write somewhat later in "An Inside Look at MS-DOS" (*Byte*, June 1983), "The primary design requirement of MS-DOS was CP/M-80 translation compatibility."

An early article by David Cortesi, "CP/M-86 vs. MS-DOS: A Technical Comparison" (*Dr. Dobb's Journal*, July 1982), compared MS-DOS with both CP/M-80 (for the Intel 8080) and CP/M-86 (for the 8086), showing not only where MS-DOS properly emulated CP/M functions but also where there were differences. For example, Function 9 outputs strings terminated with a $ character in both systems, but CP/M expanded tabs and MS-DOS didn't. In any case, the $ itself is a reminder of MS-DOS's CP/M roots. To this day, MS-DOS contains many holdovers from its early start as a CP/M clone. The PSP, for example, is nothing more than a CP/M base page.

However, even at the beginning, there were crucial differences between the two systems. MS-DOS did not support CP/M function calls 12 (0Ch) to get the system version number. Somewhat more essentially, MS-DOS 1 stole the last few bytes from function 0Ch to read the keyboard.

The most significant difference was in the file system. In an important departure from the CP/M file system, MS-DOS internally used a file allocation table (FAT), a scheme borrowed from Microsoft stand-alone BASIC. Paterson's original goal was to make the FAT memory resident at all times, thus saving the extra disk reads that CP/M often made just to find where a file's data was located. As Rae Duncan noted in PC Tech Notes, "To Bill Software Toolbox, columns, *Dr. Dobb's Journal*, November 1982, "Although the systems appear very similar, the two disk cards differ in their allocation schemes ... to a great degree. This has a significant effect on the speed of disk operations."

So MS-DOS again was unencumbered. Some of CP/M Digital Research, makers of CP/M, went on to write many other operating systems, such as Concurrent CP/M, DEXOS, GEM, Personal DOS, MP/M, Real/32, DOS Plus, and finally DR DOS. DR DOS was intended as a complete replacement for MS-DOS. Its command set now is compatible with the original's quirks.

DR DOS even shows its CP/M roots. For one thing, the DR DOS disks and manuals carry copyright dates going back to 1976. Second, the code in DR DOS may never go back to its original CP/M code base. All of the CP/M-86 versions such as PIP or CCP in the DR DOS manuals are available. DR DOS debugger, for example, is not called DDT; the DR DOS kernel is still called BDOS, just as in older days.

For example, the DR DOS SYS device driver has a BDOS option to relocate the DR DOS kernel to the HMA or not. MS-DOS 5.0's DOS=HIGH command first appeared many years later. With providing more features than Microsoft, sooner than Microsoft, DR DOS still has the original CP/M heritage at least in its naming conventions.

Novell's ownership never much changed. Except that Novell acquired Digital Research in 1980, renamed it in late 1985, DR DOS now is named Novell DOS. Novell shares in some of the success of NetWare. NetWare dominates the network operating system market, surpassing any of Microsoft's networking products, providing network software. Novell's purchase of DR DOS is now a whole new ballgame, since DR DOS sales have dropped almost to zero since the Novell purchase. However, the drop is also due to Novell's purchase of DR DOS due to Microsoft's release of MS-DOS 5.0. DR DOS had its best quarter in the second quarter of 1990, just before 1991, when Digital and DR DOS sued Microsoft. Today is the sad tale. MS-DOS was engineered largely by IBM.

DR DOS was the only alternative operating system for MS-DOS which has a lot to say about Microsoft's role since DR DOS's entry into the market. DR claimed to have sold more than 1,500,000 copies of DR DOS 5.0 in 1991, which is a huge success was short-lived. Based on the actual shipments of MS-DOS 4.0, Novell estimated that DR DOS now controls 8.1% of the MS-DOS market. *PC Magazine*, April 27, 1993, p. 30. DR DOS's share is 5% in 1991, when Microsoft sold 50% of the installed world of MS-DOS. DR's total revenue was $30 million. Assuming that DR sold nothing but DOS and assuming that each copy was the same, DR DOS and MS-DOS sales would be 1.5 million copies of DR DOS and 30 million copies of MS-DOS. DR DOS's presence was strong in Europe and the United States, possibly in part because DR DOS was born out of Novell's European Development Center in Hertfordshire, England.

DR DOS has a huge "chip on its shoulder" attitude. More than one reviewer of this book noted that we were "not very subtle" in the first place. Angrily reporting DR DOS's claims of MS-DOS compatibility, one reviewer noted that a Microsoft employee dismissed the idea of anyone actually checking out the presence of this "imported crime" and blamed us "I see no reason why we should not expect to see DR selectively because programmers share their development and marketing costs." This reflects a general feeling that DR DOS is Brand X and pretty much irrelevant. For example, in an article on operating system choices for the 1990s, *PC Magazine*, January 15, 1991, Charles Petzold placed DR DOS in the "Interesting But Does It Really Matter Department."

But consider the economics of DOS. For example, in its 1991 fiscal year, which ended in June 1991, Microsoft had total revenues of $1.843 million. Of this, Windows, through new Windows applications like Excel and Word, brought in $708 million, or 38.4 percent. Meanwhile, MS-DOS, OEM plus retail sales, again not spectacular, brought in more than twice that much, $1,617.5 million, which represents a whopping 87.7 percent of Microsoft's revenues.

Now notice that a company takes only 5 percent of this business from Microsoft, it has made $30 million. One could run a 300 person company on sales like those. As a matter of fact, in 1991 Dell had total revenues of $546.5 million. At the time, it had 290 employees.

What's so strategic, in Novell DOS, about this alternative to MS-DOS that's become more important? This is not only because Novell DOS is a better product than DR DOS and because Novell DOS has stronger ties to NetWare, but also because Novell DOS is, as you'll see, much more compatible with undocumented aspects of MS-DOS that were clones of DR DOS's [illegible].

Why would anyone prefer DR DOS rather than MS-DOS? One reason is the price of DR DOS to computer manufacturers, who must bundle a copy of DOS with every machine. Microsoft's licenses between $10 and $25 for an OEM copy of MS-DOS. DR DOS's OEM prices are lower. Manes and Andrews *[illegible]* mention a 1988 price of $6 for DR DOS. Thus a manufacturer might consider bundling DR DOS rather than MS-DOS for the same reason that they might consider using a 386 chip from AMD or Cyrix rather than from Intel.

On the other hand, there's Microsoft's hegemony that is next to impossible to avoid on machines bundled with DR DOS rather than MS-DOS. Isn't it surprising that Microsoft has no competition in its traditionally lucrative market for the copies of DOS installed on every single PC? This may be a product of Microsoft's OEM pricing of MS-DOS on a per-machine rather than a per-copy basis. As Manes and Andrews note, it becomes extensive discussion of MS-DOS OEM pricing, "per machine declarations are nearly impossible to track. DOS monopolies [illegible] were literally paying a royalty to IBM on every machine sold. You weren't likely to collect a penny when someone else's high-priced hardware [illegible] 266."

Another possible reason is how DR DOS might be, but DR DOS generally leads MS-DOS in features. The time line in Table 4-1 makes this clear.

Table 4-1: Novell and DRI vs. Microsoft, A Timeline

August 1990	DR DOS 5.0, HIDOS=ON, etc.
June 1991	MS-DOS 5.0, DOS=HIGH, etc.
July 1991	Novell purchase of Digital Research
September 1991	DR DOS 6.0 with compression
September 1991	NetWare Lite
October 1992	Windows for Workgroups 3.1
April 1993	MS-DOS 6.0, DoubleSpace, etc.
April 1993	Novell announcement of Novell DOS 7.0 and NetWare 4.1

DR DOS 5.0 and Novell DOS 6.0 were both Digital Research releases almost a year before MS-DOS and it came bundled with disk compression. NetWare Lite, from AddStor, was over a year before MS-DOS. Microsoft's first release of Windows for Workgroups, WfW, came more than a year after Novell and DRI were [illegible]. NetWare Lite with DR DOS, though better WfW and NetWare Lite lag far behind Artisoft's LANtastic in the peer-to-peer networking race. DR DOS appears to have been [illegible] MS-DOS. And what is perhaps by now important, the [illegible] of MS-DOS 5.0 [illegible] were available for OEM customers earlier than ready to OEMs for bundling with their machines, also comes from DR DOS. DR DOS 5.0 was the first retail DOS.

Basically, if you want to find out what features the next version of MS-DOS might support, you can look at the current version of DR DOS. However, it is not necessarily true that Microsoft's real

copies of its free DR DOS. For that to be true, there would need to be more of a time lag between say, DR DOS release and the subsequent release of the MS DOS version with similar features.

Microsoft has been accused of carefully orchestrating leaks about future versions of MS DOS in an attempt to create what in the industry is called FUD: fear, uncertainty and doubt regarding DR DOS. For example, in October 1990, shortly after the release of DR DOS 5.0 and only before the release of MS DOS 5.0, stories on features and enhancements in MS DOS started to appear in *InfoWorld* and *PC Week*. Brad Silverberg, Vice President of Systems Software at Microsoft and General Manager of Windows and MS DOS Business Unit, wrote a forceful letter to *PC Week* November 5, 1990, denying that Microsoft was engaged in FUD tactics. "To serve our customers better, we do intend to be more forthcoming about version 5.0," and denying that Microsoft copied features from DR DOS. "The features and enhancements of MS DOS version 5.0 were decided and developed long before we heard about DR DOS 5.0. There will be some similar features. With almost four MS DOS users, it shouldn't be surprising that DRI has heard some of the same requests from customers that we have."

We can only speculate as to what was said about Microsoft's trying to match features in DR DOS. We should be grateful to DR DOS for whatever little competition it poses MS DOS, and for whatever pressure it puts on Microsoft to keep improving DOS. The paper we have just read makes it quite clear that DOS is not good enough as it is. The present stagnation of DOS is not caused by a lack of competition, but by conditions of near monopoly. But with its planned integration of DOS 7.0, Windows 4.0, Microsoft will hopefully make some of the improvements to DOS and applications we take for granted in Novell NetWare.

We have a lot more sympathy for DR DOS rather than MS DOS. In making such a statement, it is important to note that DR DOS is not MS DOS. As we see in this chapter, DR DOS not only has features not found in MS DOS but also has many compatibility differences in both documented and undocumented areas of the DOS interface.

Just as Novell DOS 7.0 is a significant upgrade of its operating system, Novell has reworked many of DR DOS internals and the new Novell DOS product is now much more compatible with MS DOS and supports a major subset of NetWare 4.0. It will be interesting to see if Novell can use its clearly dominant NetWare position to push DOS, perhaps by tightly integrating Novell DOS and NetWare.

The DR DOS Version Number

The first and most obvious question many programmers have about DR DOS is what version are you to report for DR DOS, which version of DOS are you running under? This is an important enough question that the *DR DOS 6.0 Operations and Configuration Manual* has a whole section in the appendix on how to detect DR DOS and how to report that DR DOS will appear to be COMPAQ DOS 3.31 or Novell DOS 7 (see DOS Get Version function INT 21h AH=30h, Classic Code [103h, 3.31]).

Novell DR DOS 7 can also report itself as 3.31. This is an interesting case of masquerading because the Novell version is actually based on 80x86 machines rather than 8086s. There is a nice Irish expression for this: "the poor mouth" (see the title of a delightful book by Flann O'Brien). Some software developers, in the interests of being poor, or at least rare, use instances to gain advantage for software licensing or prospective customers. We don't know about the creditors part, but given that DR DOS can emulate MS DOS, it is surprising to learn that DR DOS puts on the poor mouth. Rather than report itself as DOS 5.0 or 6.0, it reports as DOS 3.31.

Other software developers, by contrast, write DOS programs to version checking improperly that is, they require that DOS be a specific version. This is largely the case for the otherwise idiotic SLIVER command in MS DOS. Some programmers check simply naively for DOS 3.0 (or example, looking for DOS 3.0 *and greater*), but they need to be fooled into thinking that DOS 5.0 is really DOS 3.0 in order to make SLIVER work. There is no DR DOS equivalent to SLIVER.

A major reason DR DOS sticks to the DOS 3.31 version number is that this makes it much easier to run Microsoft Windows. Other DOS clones such as General Software's Embedded DOS and Datalight's ROM-DOS also state the 3.31 version number in order to run Windows. As Chapter 1 discussed, the IFSMGR component of Windows Enhanced mode expects to be able to carry out a lot of back door communications with any DOS that reports version 5.0 or higher. As we were going to press, Novell announced that Novell DOS 7 would report DOS version 6.0. Novell DOS 7 implements the DOSMGR interface.

Given that any DR and Novell DOS versions report themselves as DOS 3.31, applications have a difficult time determining when they are running under DR DOS rather than MS DOS. Of course, if DR DOS were 100% compatible with MS DOS this wouldn't matter. However, there are enough differences that sometimes it matters a great deal.

For example, Stac Electronics' *Stacker 2.0 for Windows* has a short appendix, "Programming with Stacker," which is licensed for the Stacker API, which must be licensed separately from Stacker, containing sample code for use with Stacker drivers. See the FNUMDRV program in Chapter 8. This source code contains the following comments:

```
; This function uses the removable media IOCTL call (21/4408) to
; detect Stacker drives.  However, under DR DOS 5.0, the get
; logical device call (440EH) is used, since DR DOS does NOT
; pass these (4408h) calls through to the Stacker device driver.
```

If you examine the code itself, however, you discover that it checks simply for a DOS version of 3.31. It then appears to test for DR DOS by comparing the vendor string returned by INT 21h, AX=3000h with "DRDOS". Unfortunately, this test fails on Novell DOS 7 because Novell changed the vendor string to "NOVELL". Actually, I would be willing to bet that Novell DOS 7 will report DR DOS 6.0 to Stacker 2.0 for Windows.

Another example: DR DOS will use a special protection scheme in XtreeGold 2.0. According to the makers of Xtree, Digital Research has not released the undocumented MS DOS variables to some of their application programs. DR DOS 5.0 provides compatible values. (*PC Week*, July 17, 1991). Apparently, Digital Xtree was getting the internal pointers by reading undocumented MS DOS functions (such as undocumented Current Directory Structure). As explained in this book, Novell rewrote the DR DOS kernel so that DR DOS would not have to keep track of the DOS current directory. I'm sure one reason for Xtree Gold's different treatment of its code between DR DOS and MS DOS is perhaps to avoid having to keep the Novell Get Current Directory call.

Undocumented Novell DOS

So how can a DOS program determine if it is running under DR DOS and not MS DOS or Compaq 3.31? In Chapter 1 we saw how Microsoft's VARD code in Windows differentiates between genuine MS DOS and non-Microsoft DOS. Actually, this is not a valid way of testing for an environment.

DR DOS has two environment variables, OS and VER, which are not found in versions such as OS=DR4DOS and VER 6.0, but it would be foolish to rely on these as any test of version. SET VER or SET OS from the command line will display the values. Indeed, the VER command in DR DOS displays "DR DOS Release XXX" where XXX comes from the VER environment variable. But this can easily change. Relying on these variables is a bad idea.

Novell DOS 7 supports undocumented versions of INT 21h AH=43h and AH=44h. The AH=43h functions seem to be a Novell hook documented or used for controlling password security and for undelete. DOSWatch Some of the AH=44h functions INT 2Ah AX=4410h through AX=4418h are obsolete as DOS 4.x provided more than the documented MS DOS IOCTL codes which currently go up to AX=440Fh, Query IOCTL Device. However, these functions have expanded in the range AX=4450h through AX=4458h, which Novell will continue to support. Table 4.2 shows the DR DOS extensions to INT 21h; see the appendix and INTRLIST on disk for further details.

Table 4-2: DR DOS INT 21h Functions

AX=4302h	Get Access Rights (documented in DR DOS 6.0+)
AX=4303h	Set Access Rights and Password (documented)
AX=4304h	Get Encrypted Password
AX=4305h	Set Extended File Attributes
AX=4306h	Get File Owner
AX=4307h	Set File Owner
AX=4380h	Undelete Pending Delete file (Novell DOS 7.0)
AX=4381h	Purge Pending Delete file (Novell DOS 7.0)
AX=4451h	Concurrent DOS Install Check
AX=4452h	Get DR DOS Version
AX=4453h	Set Global Password
AX=4454h	DR DOS History Buffer Control
AX=4455h	Get/Set Share -Unload Status
AX=4458h	Get Pointer to Internal Variable Table
AX=4E00h	(CX=88h) Find First Deleted File
AX=4E00h	(if 4E-h had CX=88h) Find Next Deleted File

The DR DOS version variable is INT 21h AX=4452h Get DR DOS Version. It is probably not coincidental that 4452h is the ASCII code for the initials DR. Under DR DOS and Novell DOS this function returns a DR product code in AX and in Novell DOS 7.0 release code in DX. Elsewhere such as under MS-DOS this function should return with the carry flag set and/or with the value in AX unchanged. The DRI multi-task products such as Concurrent DOS and Multiuser DOS use a similar function, INT 21h AX=4451h.

Digital Research DR-DOS latter on method has unfortunately been a closely guarded DRI secret. As Steven Scrupps reported Jeremy Reed in DRI's then head office in Germany: "I just had a big OEM negotiation on the phone who asked me if the system can detect DR DOS. I had to tell him no, there is no way. The best detection is MS-DOS 3.3x and DR DOS 5.0 are absolutely the same."

Novell Digital Research has finally given up the policy of pretending that DR DOS is identical to MS-DOS and in the Digital Research Programmer's Guide (DR product #1182 2013 000) the very existence of such functions was confirmed. DR DOS programmers should now be able to obtain the necessary information from Novell's developer relations group. Assist DX=1 is the case which, for instance, detects a few DR DOS specific functions such as AX=4452h and AX=4B03h, set Int 24h=2, and the DataMAX INT 2Fh AH=27h interface, the main problem remains the unsupported piece of information that most developers want about DR DOS, which is how to detect that you're running under it.

The DR DOS version codes do not use simple DOS version numbers. Instead they indicate the code for a DRDOS product and version numbers go all the way back to function 12 in CP/M 80. Table 4-3 shows the key version numbers.

Table 4-3: 1067h and All That. Novell/DR BDOS Product Codes

1063h	DR DOS 3.41
1065h	DR DOS 5.0
1067h	DR DOS 6.0
1070h	DR PalmDOS
1071h	DR DOS 6.0 Update 1993, potentially WIN
1072h	Novell DOS 7.0
1466h	DR Multiuser DOS 5.1
1467h	Concurrent DOS v5.1

As you can see, single-user (though possibly multitasking) such as Novell DOS 7.0 operating systems use version 10h and multiuser systems use 14h. Function 4452h only works under the single-user systems such as DR-DOS and 4451h works only under the multiuser systems such as Concurrent DOS, DR-DOS 3.41, OEM version of DR-DOS for palmtop computers. Many of the DOS compatibility improvements found in Novell DOS 7.0 were in fact first introduced in Caldera DOS. The DOS-compatible version, first present in the March 1993 "business update" of DR-DOS, so programs that need the new EDRDOS can check for DOS=0h or higher (that is, AH > 10h or AH == 10h and AL >= 70h).

All this can be wrapped up in a C callable `drdos` function shown in Listing 4-1, IS_DRDOS.C. You can incorporate this code in other programs or by compiling it with `-DSTANDALONE` can run it as a stand-alone test. You might contrast the straightforward nature of this code with the strangeness of MSDFTECT.C in Chapter 1.

Listing 4-1: IS_DRDOS.C

```
/*
IS_DRDOS.C
Andrew Schulman, January 1993
With changes by John (Frotz) Fa'atuai of Novell, February 1993
From "Undocumented DOS", 2nd edition (Addison-Wesley, 1993)

To link with other programs:  bcc -c is_drdos.c
To make standalone test:      bcc -DSTANDALONE is_drdos.c
*/

#include <stdlib.h>
#include <stdio.h>
#include <dos.h>

typedef unsigned short WORD;

/* EDC = European Development Centre, Novell Digital Research
   Systems Group, Hungerford, England */
WORD EDC_product_codes(WORD api_function);
{
    _asm mov ax, api_function
    _asm stc                    /* set carry flag */
    _asm int 21h
    _asm jc no_drdos            /* carry set: function not supported */
    _asm cmp ax, api_function
    _asm je no_drdos            /* AX unchanged, function not supported */
have_drdos:
    _asm jmp short done         /* carry clear and AX changed */
no_drdos:
    _asm xor ax, ax             /* not supported, return AX=0 */
done:;
    /* return value in AX */
}

WORD is_drdos(void)
{
    WORD product_code;

    /* Try the single-user API call */
    if ((product_code = EDC_product_codes(0x4452)) != 0)
        return product_code;

    /* Try the multi-user API call */
    if ((product_code = EDC_product_codes(0x4451)) != 0)
        return product_code;

#if 1
    /* The following seems like a bad idea, because the documented
       call is already up to AX=4411h (Query IOCTL Device)! */
#else
```

```
    /* Try an _old_and_obsolete_ single-user API call */
    if (product_code = EDC_product_codes(0x4412)) != 0)
        return product_code;
#endif
    /* still here:  definitely no DR DOS! */
    return 0;
}
#ifdef STANDALONE
main()
{
    WORD EDC_product;

    if ((EDC_product = is_drdos()) == 0)
        printf("Single- or Multi-user DR DOS not running\n");
    else
    {
        switch (EDC_product)
        {
            case 0x1060: printf("DOS Plus"); break;
            case 0x1063: printf("DR DOS 3.41"); break;
            case 0x1064: printf("DR DOS 3.42"); break;
            case 0x1065: printf("DR DOS 5.0"); break;
            case 0x1067: printf("DR DOS 6.0"); break;
            case 0x1070: printf("DR DOS Peim0S"); break;
            case 0x1071: printf("DR DOS 6.0 March 1993 update"); break;
            case 0x1072: printf("Novell DOS 7.0"); break;

            case 0x1452: printf("Concurrent PC-DOS 3.2"); break;
            case 0x1441: printf("Concurrent DOS 4.1"); break;
            case 0x1450: printf("Concurrent DOS/XM 5.0 or "
                                "Concurrent DOS/386 1.1"); break;
            case 0x1460: printf("Concurrent DOS/XM 6.0 or "
                                "Concurrent DOS/386 2.0"); break;
            case 0x1462: printf("Concurrent DOS/XM 6.2 or "
                                "Concurrent DOS/386 3.0"); break;
            case 0x1466: printf("DR Multiuser DOS 5.1"); break;
            case 0x1467: printf("Concurrent DOS 5.1"); break;
            default:     printf("unknown DR DOS version"); break;
        }
        printf(" (BDOS 104Xh)\n", EDC_product);
        printf("Providing DOS interface as %02u\n", osmajor, osminor);
    }
    return (EDC_product);
}
#endif
```

IS DRDOS has been tested under MS DOS 5.0 and 6.0 where it correctly outputs "Single- or Multi-user DR DOS not running" and under DR DOS 5.0, 6.0, Novell DOS 7.0 and under Concurrent DOS 3.2, 4.1, 5.0, 6.0 (which one of these I purchased at the World Still Warehouse in Sunnyvale CA [home of dead hardware and software for $14.95]).

Of course, any software that tries to circumvent DR DOS and Novell DOS call function 4452h to work as they were designed to work under DR DOS. For example, if you take COMMAND.COM or SHARE.EXE from DR DOS 6.0 and run them under MS DOS 6.0, they will complain "Incorrect version of operating system." Unfortunately, this is not done consistently. For example, the MEM utility of DR DOS 6.0 runs under MS DOS and while it generally produces correct results, the /S ("Shows system structures") option fails to ensure that it is indeed running under DR DOS, causing DR's MEM/S under MS DOS hangs the system.

Watching DR DOS

Assuming one already knows about the undocumented DR DOS functions, how does one go about determining which DR DOS or Int 21h services they use? The INTRSPY utility presented in Chapter 5, is perfect for this. The DRDOS.SCR script shown in Listing 4-2 lets INTRSPY watch some selected DR DOS functions. In addition to the INT 21h extensions from Table 4-2, DRDOS.SCR also reports on INT 2Fh AX=12FFh, which the MEMMAX utility uses.

Listing 4-2: INTRSPY Script for Selected DR DOS Functions

```
; DRDOS.SCR
intercept 21h
    function 43h on_entry
        if (al > 1)
            output "21/43/" al
    function 44h on_entry
        if (al > 11h)
            output "21/44/  al
    function 4bh on_entry
        output (DS:DX->byte,asciiz,64)
intercept 2fh
    function 12h
        subfunction 0FFh on_entry
            output "2F/12FF/" bx "/" cx "/" dx
```

Figure 4-1 shows a sample INTRSPY output when running the simple MEM and MEMMAX utilities in DR DOS 6.0.

Figure 4-1: Undocumented DR DOS Calls from MEM and MAXMEM (DR DOS 6.0)

```
A \MEM.EXE
21/44/52
21/44/52
21/44/58
2F/12FF/0006/0000/0000
21/44/58
2F/12FF/0006/0000/0000
21/44/58
21/44/58
21/44/57
21/44/56
21/44/56
21/44/57
21/44/56
21/44/56
A \MEMMAX.EXE
2F/12FF/0006/0000/0000
2F/12FF/0006/0000/0000
2F/12FF/0006/0000/0000
21/44/57
21/44/56
21/44/56
```

To effectively use INTRSPY, however, you must already know what you are looking for. INTRSPY is good for checking that MEM and MAXMEM call INT 21h AX=4452h, but to write DRDOS.SCR, you had to know already that DR DOS makes IOCTL calls with handle numbers greater than 11. How does one figure that out?

Disassembling DR DOS

Through disassembly of the DR DOS files, of course. The system files in DR DOS are called IBMBIO.COM and IBMDOS.COM. The command interpreter is, of course, COMMAND.COM.

Disassembly with a tool such as Sourcer shows, for example, that COMMAND.COM calls INT 21h AX=4452h, AX=4456h, AX=4458h, and AX=4488h. IBMDOS.COM provides these calls.

You can also disassemble the separate utilities shipped with DR DOS such as MEMEXT and MEMMAX.EXE. However, Novell compresses these programs with PKLITE, an executable file compressor (see PKWARE). To disassemble the files, you must first decompress them with the PKLITE /d switch. PKLITE is readily available electronically, for example, from the IBMSYS forum on CompuServe.

Without studying the source, MEMMAX utility, which in DR DOS enables, disables, and displays the status of upper memory and the lower memory, I can offer the following: Novell's MEMMAX.EXE version 2.0 (Dissembler by Sourcer produces a small 10-page listing, in which it was easy to find the code that handles the MEMMAX switches, such as /L to open upper memory for LH/LOADHI. /U to close it. /A to open upper memory for loading space, and /S to open the first 64K of memory, similar to EMM386.EXE in MS DOS 5, and so on).

Some of MEMMAX.EXE's code is unique, for example, how DR DOS enables and disables upper memory. Because DR DOS 5.0 and 6.0 do not implement the MS DOS 5.0 XMS-58h functions for upper memory control, Novell DOS 7 does. MEMMAX contains whole code to manipulate the MCB chain of INT 21h AH=52h, which returns a pointer to SysVars, at which DR DOS, as we will see, stores the start segment of the first MCB. Also, SysVars+3 is a pointer to the MCB chain.

Now, to enable UMBs, INT 2Fh AX=5803h BX=1 in MS DOS will add the last MCB to the MCB chain. MEMMAX enables upper memory by setting the last MCB's M flag (not updating the last MCB's Z flag with an M!, but by manipulating the successor/predecessor MCB chain. To disable UMBs it finds the last block below A000h, sets its M flag to Z (for example, see listing 4-3 later in this chapter). Then it finds the new last block and sets its M flag to Z. UMBs can also be disabled via INT 21h AH=58h functions 2 and 3.

Subfunctions 0, 1, 2, and 3 of function 52h are undocumented. MEMMAX does not use undocumented subfunctions of function INT 21h AX=1211h BX=0 DX=0 with subfunction numbers in CX:

```
0       get status of video memory space (memmax /v)
1       map memory into video memory space (memmax +v)
2       unmap memory from video memory space (memmax -v)
```

Also, INT 21h AX=4451h is undocumented inside IBMDOS.SYS.

How Close Is DR DOS to MS DOS?

DR DOS's goal is to be as close to MS DOS as possible, including its low-level systems software such as VSHARE.386 and NWSERVER.EXE, to run NetWare 4.x servers with DR DOS. The *DR DOS 6.0 Installation and Configuration Tips* manual states that DR DOS is generally compatible with applications that comply with the MS DOS 3.3 standard and that follow the standard conventions for DOS programming. Novell also claims to support partitions larger than 32 MB partitions using the COMPAQ DOS 3.31 compatible 32-bit FAT conventions. However,

> Some applications have started to go beyond these conventions and actually manipulate the undocumented DOS data structures or replace sections of the operating system code with their own. This rapidly created problems in moving to more advanced versions of DOS, especially in a multitasking environment. Novell DOS 7 is designed to cope with many of these applications, but to guarantee compatibility in the future, the manufacturer will have to design the DR DOS 6.0 operating system into account as well!

It is the application's responsibility to conform to DR DOS, but DR DOS supports only a few undocumented application interfaces. This is because, as we noted earlier, that is how *de facto* standards work: DR DOS must conform to the conventions of DOS programming, not the other way around. Hence, the new Novell DOS 7 kernel

Indeed with each release DR DOS has incorporated support for more and more of the *de facto* DOS programming standards. DR DOS started out as Concurrent DOS. DR stripped out the concurrent and multiuser parts and added an MS DOS compatibility layer. Additional MS DOS compatibility was added with each release as it seemed to be needed. One gets the feeling that DRI's policy of supporting one or another undocumented DOS internal data structure, such as the Current Directory Structure, for as long as it could. This produced some compatibility problems, such as those noted earlier with Xtree. In Novell DOS 7.0, however, and in OpenDOS 7.01, there is finally a version that works like MS DOS 3.31. Note, however, that even these newer versions do not pass the Ingalls arbitrary test made by Microsoft Windows VARD detection code discussed in Chapter 1.

A technical support engineer at Novell reports that "many of our escalated technical support problems with developers are a result of differences that DR DOS 6.0 has with respect to DR-Net packages used within *Undocumented DOS*." Presumably some of these problems are fixed in time for the first edition of this book, but in some cases DR DOS 6.0 was simply not sufficiently compatible with undocumented but widely used aspects of MS DOS.

Clearly, life would be much easier for Novell and other builders of DOS work-alikes if DOS application programs would restrict themselves to the documented DOS interface. Seen in this light, the widespread use of undocumented DOS is a real boon to Microsoft's advantage. Novell would certainly prefer that applications avoid using undocumented DOS calls and data structures, but the same technical support engineer just quoted also reports that at Novell "our Unixware Intel UX was developed almost exclusively from *Undocumented DOS*." This effort is reported to still be ongoing. Many developers at other PC software houses suffer because of the widespread use of undocumented DOS calls and suffer further because of the widespread use of this book. Yet at the same time, these companies are most eager to show just-wish expressions of several (a few, some, restraint? Of course, Microsoft sets the standard here with its dogma that any code that uses undocumented calls

SysVars, the Current Directory Structure, and the Redirector

We've already noted that Novell's own NETX and EMSNETX programs rely on the undocumented INT 2Fh AH=52h undocumented function, so this version and at least some of its associated SysVars structures clearly must be supported by DR DOS. Many of the programs in other parts of this book will not run under DR DOS. Windows will not run properly in DR DOS enough has been said to explain why it is unlikely for this to happen. DR DOS 5 and 6 do not provide a true MS DOS 3.31 compatible DR DOS is a close approximation but not an exact duplicate of many undocumented portions of MS DOS.

However, under DR DOS 5 and 6.0, some of the internal data structures visible through undocumented DOS calls are *real* ones. These structures exist to keep applications happy, so DR DOS does not actually use these structures. Applications that *modify* rather than just query these structures may be in for a rude shock.

For example, the XLAT_DRV variable from Chapter 2 modifies the CDS pointer and LASTDRIVE fields in SysVars. XLAT_DRV appears at first to work under DR DOS. Function 52h returns a pointer to SysVars, and SysVars contains what appears to be a valid CDS pointer and a LASTDRIVE value. XLAT_DRV successfully modifies both values. However, this has no noticeable effect on the system. If the value of LASTDRIVE in CONFIG.SYS was E, and if XLAT_DRV changes the LASTDRIVE value in SysVars to F, the highest valid drive is still E. Quarterdeck's LASTDRIVE=(CONFIG) from QEMM likewise has no effect on the number of actual drives under DR DOS 5.0 and 6.0.

The problem is that DR DOS 5.0 and 6.0 keep their genuine current directory and drive information somewhere other than in the CDS. The CDS is supplied only as a CDS to satisfy programs that a CDS does indeed exist. DR DOS 5.0 and 6.0 internally store the current directory based on its first character rather than on its ASCII name. DR DOS 6.0 rebuilds the fictitious CDS at appropriate times from DRI's

sor's internal drive table and likewise the internal table is sometimes updated from the CDS but often not even that is done. A few applications needed the full pathname that it would get away without getting it. The solution is to let the CDS always holds the drive's root (for example C:\ rather than the current directory) thereby solved the problem with X recognized earlier. Likewise the SUBMENU program in Chapter 8 won't work under DR DOS 5.0 or 6.0.

You might think that DR DOS should not have to support something as sick as direct access to drive data structures via the CDS but in fact it does have to support this. So finally the new RDOS kernel in Novell DOS 7, DR DOS 6.0 March 1993 update and Novell DOS 7.0 have a genuine CDS. Changing the CDS pointer and LASTDRIVE values in SysVars really does change the DOS drive table.

Novell DOS 7 supports DR DOS 5.0 and 6.0 did provide was primarily for use by network redirectors. As Chapter 8 explains, to read the CDS from without a genuine CDS, DR DOS 5.0 and 6.0 will work compatible with most commercial redirectors, though not with our Phantom redirector from Chapter 8. Things will not work correctly, but does not use the CDS pathname buffer in just the same way as our Phantom.

In PalmDOS and Novell DOS 7.0 the network compatibility is greatly improved. For example, WfW would not run on DR DOS 5.0 and 6.0 apparently WfW relies on an obscure field in the SYSVARS, but it does work in PalmDOS and Novell DOS 7.0.

The System File Tables and SHARE

Novell DOS 7.0, DR DOS 6.0 also uses System File Table structures that are exactly identical to that found in MS DOS. The FILES parameter (see Chapter 8) works identically under DR DOS. DR DOS even supports the undocumented INT 2Fh AX=1220h function in MS DOS to get the address of an individual SFT entry.

DR DOS provides SHARE.EXE but its internal SHARE structures are radically different from those in MS DOS. DR DOS 5.0 has no SHARE hooks so read-only control of the first SFT (see SHAREHOOK.C and Chapter 8) is not possible. Most of the SHARE fields in the SFT (see the appendix) are not used, but are present even in Novell DOS 7.0. According to a developer at Novell: "We believe that there are certain problems with the level of the SHARE interface that we have continued to implement SHARE in a different way."

DR DOS does provide an INT 2Fh AX=1000h SHARE install check. DR DOS 5.0 and 6.0 return AL=0 (not installed) while Novell DOS 7 returns AL=FFh (installed). However, this has no effect on the operation of the INT 2Fh AX=1000h. As noted in Chapter 8, this function is often used by applications as a preliminary SHARE install check because Windows hooks INT 21h and checks if INT 2Fh AX=1000h has been changed. If so, it is assumed that SHARE is installed. Note that INT 2Fh AX=1000h is not documented in Microsoft's programmer's reference manuals and should not be used by third party applications. Instead, Microsoft's programmers should use the documented AX=1600h invalid function if SHARE is not installed. This does not work in DR DOS, see SHAREHOOK.C in Chapter 8.

Memory Control Blocks

DR DOS 5.0 and 6.0 use Memory Control Blocks just like those found in MS DOS. In fact, the DR DOS MCB format is so similar that it is possible to read both the program name and size of the DR DOS MCB just as in MS DOS 4.0 and above. The DR DOS MCB is identical to the MS DOS 3.31 DR DOS also adds two MCB owner types: 0BFFEh to indicate an XMS UMB and 0BFFDh to indicate a "excluded" UMB.

As we've seen elsewhere, MEMMAX.EXE and elsewhere, DR DOS itself relies on its ability to access the MCB chain directly. As noted earlier, DR DOS 5.0 and 6.0 do not support the MS DOS 5.0 API so it has to support memory control. So MEMMAX contains some code by Matthias Alles. Matthias Alles, author of a massive book from Germany on DOS programming and co-originator to much of the DR DOS information in this chapter, has written a generic UMB test functions in Turbo Pascal that work both in MS DOS 5.0 and higher and in DR DOS 5.0 and higher. These are shown in Listing 4.3.

Listing 4-3: Generic UMB Link Functions

```
{ from Arne Schapers, "DOS 5 fur Programmierer", pp  684-688 }

{ Returns TRUE if UMBs are linked in, works for MS-DOS 5, MS-DOS 6.0,
DR-DOS 5.0, and DR-DOS 6.0 }
Function GetUMBLink: Boolean;
var Regs: Registers,
    MCB: MCBPtr; p: ^Word,
begin
  if TrueDosVersion = $3203 then { DR DOS 5.0 }
  begin
    { GetDosDataArea calls INT 21h AH=52h }
    p := GetDosDataArea, Dec(LongInt(p),2),
    MCB := Ptr(p^,0),  { DOS Data Area, offset - 2 }
    while MCB^.Flag <> 'Z' do  { walk MCB chain }
      MCB := Ptr(Seg(MCB^)+1+MCB^.Size,0);
    GetUMBLink := Seg(MCB^)+MCB^.Size > $A000,
  end else
  begin
    Regs.AX := $5802,  { Function, "Get UMB Link State" }
    Intr($21,Regs);
    if Regs.Flags and FCarry <> 0 then GetUMBLink    False
      else GetUMBLink := (Regs.AL <> 0),  { TRUE if UMBs linked in }
  end,
end,

{ Tries to link UMBs in, works with MS  and DR-DOS 5.0/6.0 }
Procedure SetUMBLink(LinkState: Boolean);
var Regs: Registers,
    MCB: MCBPtr; p: ^Word,
    NextMCB  Word, Done: Boolean;
begin
  if DosVersion = $3203 then { DR-DOS 5.0 }
  begin
    p := GetDosDataArea; Dec(LongInt(p),2);
    MCB  = Ptr(p^,0),  { DOS Data Area, offset - 2 }
    Done  = False,
    { walk MCB chain to < $9FFF }
    while (MCB^.Flag <> 'Z') and not Done do
    begin
      NextMCB := Seg(MCB^)+1+MCB^.Size,
      if NextMCB >= $9FFF then Done  True
        else MCB := Ptr(NextMCB,0);
    end;
    if NextMCB < $9FFF then NextMCB  = Seg(MCB^)+1+MCB^.Size,
    if (NextMCB   $9FFF) and  { MCB with ID of MEMMAX on $9FFF }
      (MCBPtr(Ptr(NextMCB,0))^.OwnerPSP = $0007) then
    begin
      if LinkState then MCB^.Flag    'M'
        else MCB^.Flag := 'Z',
    end
     else DosError := 1;  { "Function not supported" }
  end else
  begin      { MS DOS }
    Regs.AX  = $5803,  { Function  "Set UMB Link" }
    Regs.BX  = Ord(LinkState),
    Intr($21,Regs),
    if Regs.Flags and FCarry <> 0 then DosError  = Regs.AX
      else DosError  = 0,
  end,
end;
```

O is DR DOS 5.0 and 6.0 require these replacements as Novell DOS 7.0 implements the DOS 5.0 INT 21h AX=5802h and AX=5803h functions.

TSRs and the Swappable Data Area

DR DOS implements all the commonly undocumented functions commonly used by memory resident DOS programs. These functions include INT 21h AH=34h Get InDOS flag, AH=50h Set PSP, AH=51h Get PSP, AX=5D06h Get Extended Error Information, and INT 28h Keyboard Idle. DOS TSRs run under DR DOS without incident.

DR DOS even implements undocumented DOS functions INT 21h AX=5D06h which returns a pointer to the Swappable Data Area. Some TSRs use this to swap the DOS state (see Chapter 9). While the fields in the SDA are the same as in MS DOS, most programs don't look at individual fields in the SDA. They just swap the entire structure, using the swap and swap always sizes returned from function 5D06h. This appears to work under all versions of DR DOS, though naturally the entire DOS state is not contained in the SDA. Note that this is true in MS DOS as well. Writing SDA swapping TSRs is risky business.

Additional DR DOS and Novell DOS Functionality

Having looked at how DR DOS falls just slightly short of MS DOS in implementing various undocumented DOS functions and structures, let's take a moment to look at what *additional* functionality DR DOS provides for programmers.

The most important extra DR DOS hot item is of course the DR DOS detection call: INT 21h AX=4452h. Because, however, there are a number of other undocumented DR DOS functions, it seems unlikely that programmers would want to write DR DOS specific software. The only thing that makes such software practical is if DOS with this call is a large market. It is more likely that programmers would want to take advantage of some of the documented interfaces provided in DR DOS and Novell DOS, such as the DeskMate task switching APIs which Novell documents in a specification on "File and Directory Salvage for DOS Media."

Even if MS DOS 6 includes task switching, added to DR DOS 6.0 has a secret INT 21h AH=27h function as described in the *DR DOS 6.0 Function and Programmers Guide*, August 1991. INT 21h AX=2704h registers a new task manager. The Virus/MAX CLEAN.EXE program (see Chapter 18) registers the taskMAX pop up menu system.

In Novell DOS 7, KRNL386.SYS provides basic preemptive multitasking capabilities. If KRNL386.SYS is loaded, Novell DOS 7 also provides all API services supporting either the 0.90 or 1.0 version of the DPMI specification. All the DPMI API programs from Chapter 3 run under Novell DOS 7 if KRNL386.SYS is loaded with DPMI support enabled.

Novell DOS 7 has a set of services called the DOS Protected Mode Services (DPMS). A DPMS application programming interface is available from Novell. (See the Interrupt List on disk, INT 21h AX=4310h.)

The name DPMS sounds a lot like DPMI, and looks like the common American acronym for pre-meditated murder, but has little to do with either. DPMS is a set of services that allow DOS TSRs and device drivers to move themselves into extended memory and run in protected mode. The key feature DPMS adds to make it even easier to port TSRs and device drivers to protected mode. For example, the DPMS toolkit includes a sample protected mode VDISK.

DPMS is significant because Novell is using it for its own utilities, not only in Novell DOS 7.0, but also in NetWare Lite. Novell plans to use DPMS for disk cache and compression software, CD ROM extensions, resident workstation management utilities, workstation shells, redirectors, and requesters.

Protected Mode DOS

DPMS is just one part of a general move toward protected mode DOS. Of course, for years there have been DOS extenders such as Phar Lap's 286 DOS Extender and 386 DOS Extender. DOS extenders continue to grow in importance—witness the incorporation of Phar Lap's 386 DOS Extender in most of Microsoft's new application software for DOS, including FoxPro, Microsoft C, Visual C++, and Microsoft FORTRAN.

However, DPMS illustrates a somewhat newer trend: moving pieces of the operating system itself into protected mode. In addition to Novell, whose DPMS is likely to play an important role in NetWare DOS 7.0 and NetWare Lite, other companies are also working on moving TSRs and device drivers out of conventional memory and into protected mode.

In version 3 of its NetRoom memory management utility, Helix Software has introduced a "Cloaking API." Like DPMS, Cloaking is a method for moving TSRs and device drivers into protected mode. Helix has gone beyond this, providing cloaked versions of the system BIOS and video BIOS, both co-developed with Award Software. According to Helix, the cloaked BIOSs occupy only 8K of conventional memory instead of the normal 96K. The extra 88K becomes available as UMBs. The Cloaking API works as an extension to the EMS and XMS interfaces in real mode and uses INT 2Ch in protected mode.

Probably the most important effort to move pieces of DOS into protected mode is coming from Microsoft itself in Windows for Workgroups (WfW). While WfW may be relatively insignificant as networking software (it includes a number of virtual device drivers (see Chapters 1 and 3) that replace parts of MS-DOS), WfW 3.11 includes VSHARE.386, VREDIR.386, and VFAT.386, which contain 32-bit protected mode code for SHARE, the network redirector, and even the FAT file system. These VxDs are also part of Microsoft's Chicago, which will provide an entire protected mode operating system.

Novell NetWare

Novell's most significant product is not its DR-DOS, of course, but its network operating system NetWare, which includes [illegible] network software, such as NetWare Name Service, NetWare Management, and NetWare Client for Windows. Novell has made efforts to [illegible] the Microsoft dominance in other PC software areas, but it has been most successful in the operating systems. As networks increase in importance, so will [illegible] NetWare, Microsoft, and Novell.

How does NetWare relate to DOS? NetWare has its own set of DOS functions that it uses to the NetWare operating system itself, as well as [illegible] the system calls when a NetWare 3.0 and higher supports [illegible] multitasking and a form of dynamic linking called NetWare Loadable Modules (NLMs).

On a client workstation, however, the NetWare shell (NETX, or its [illegible] DOS. When a DOS program tries to open a file on a NetWare disk, for example, NetWare detects whether the file is actually located on a file server rather than on a local disk. If it is, NetWare intercepts the call to the NetWare file server. As we will see, NETX works by adding to the INT 21h interface, where it effectively *replaces* large parts of DOS. [illegible] has happened in other DOSs.

As Chapter 8 discusses in detail, DOS provides a well-documented INT 21h interface, allowing such software as network redirectors to intercept it. However, NetWare did not start using the network redirector interface until version 4.0.

NETX and INT 21h

In NetWare 2.0 and 3.0, the workstation shell hooks INT 21h and looks for relevant calls. Novell sometimes calls this a "shell" or "front-end requester" because NETX hooks interrupts in front of DOS. DOS can't handle a request, NETX chains to the previous INT 21h handler; otherwise, NETX builds a NetWare request packet to the appropriate file server. The NetWare shell communicates with the file server using the "proprietary" (read undocumented) NetWare Core Protocol (NCP). The shell sends NCP packets to the file server using Novell's low-level IPX protocol.

NetWare workstations hook INT 13h (primary INT 24h critical error) and INT 21h. To keep track of ask terminate hook (and INT 20h and INT 27h termination and TSR routines).

Because any file open call (INT 21h AH=3Dh or AH=6Ch) must be handled by a NetWare file server rather than locally, the DOS NETX converts the *drive mapping*. Any file open request involving drive C: might refer to the local hard disk, while a file open request for I:\DOS\AUTOEXEC.BAT refers to the file \DOS\BAT on a volume such as SYS:PUBLIC on a file server. Information on the workstation's drive mappings. NETX uses several tables: the Drive Flag Table, Drive Handle Table, and Drive Connection ID Table. Novell documents all these in the NetWare *System Internals Reference* (Chapter 5, Connection and Workstation Environment Services; Chapter 7, Directory Services).

The Drive Flag Table has 32 entries that correspond to a workstation's 32 drives. These are drives A: through Z:, plus additional network-specific drives with drive letters [illegible] and, unfortunately, Drive Major and Drive Minor. Novell NetWare had apparently not read Dr. Seuss's children's book *Oh, the Places You'll Go!* (or at least its information on the letters that come after Z:). Whenever NETX's INT 21h handler intercepts a drive-specific request, it can consult the Drive Flag Table to see if the specified drive is a local or remote drive. For remote drives, NETX can then use the Drive Connection ID table to find the file server to which the workstation drive is mapped. For local drives, NETX chains to the previous INT 21h handler.

When a DOS program opens a file on a NetWare server, it gets back a file handle just as in DOS without NetWare. NETX builds its own Job File Table (JFT) associated with the program's PSP. As [illegible] Chapter 8, JFT entries normally refer to the System File Table inside NetWare. However, a file handle can be a negative number, starting with FFh and working backward. When NETX intercepts a DOS call that refers to a file handle, it looks in the JFT to see if the file handle refers to a local or remote file. NETX maintains its own JFT for each program that NetWare services. In recent versions of NetWare, the reverse file handle starting value for NETX can be specified in SHELL.CFG or NET.CFG. This means that the maximum number of open files across NetWare can be *increased* by having a large value such as FILE HANDLES=250 in SHELL.CFG. Like many TSR programs, NETX modifies and extends standard DOS practice; this one goes [illegible] in NetWare 4.0 DOS Requester, where Novell uses the DOS redirector, thereby doing away with the need for separate file handles.

[illegible] the goal here. A DOS program should be able to access files on a NetWare server [illegible] with the same DOS calls it uses to access local files; it should not need to be aware of the difference.

Occasionally, some applications will need to be NetWare aware. NetWare provides a large set of [illegible] INT 21h; that is another reason why NetWare hooks INT 21h. For example, AX=EF00h or the Drive Handle Table, AX=EF01h or Get Drive Flag Table, AX=EF02h or Get Drive Connection ID Table, and AX=EF04h or Get File Server Name Table.

Chapter 8's MSDRV program, or Chapter 8, which walks the DOS Current Directory Structure, is [illegible] the current directory for each drive. Assuming that such a program is really useful (on the local hard disk under NetWare), it would be important for ENUMDRV to have several new CDS/NetWare aware versions of ENUMDRV could walk each of the NETX tables in the same way it now walks the CDS. It could also call INT 21h, AX=F201h, Get Directory Path, to turn directory handles into readable directory pathnames. Actually, while

ENUMDRV could use NetWare API calls to inspect the NETX tables it would be easier to determine the names of redirected network drives and printers with DOS function 5Fh/02h Get Assign List Entry; see NETDRV.C in Chapter 8. This works because NETX handles the INT 21h AH=5Fh call.

Programming NetWare with the extended INT 21h calls is an enormous subject. For more information see Charles Rose's *Programmer's Guide to NetWare* or the "Novell's Extended DOS Services" chapter in Barry Nance's *Network Programming in C*. Ralph Davis' *NetWare Programmer's Guide* discusses the same subject but using Novell's somewhat defective NetWare C Interface library, rather than with direct INT 21h calls.

NetWare 4.0 and the Network Redirector

NetWare 4.0 has a complete new architecture. As Novell notes "Technology outgrew the roughly seven-year-old NETX shell." Apparently one reason Novell wanted to move to an INT 2Fh AH=11h redirector and away from hooking INT 21h was that it became impossible to modify NETX every time a new version of DOS came out. NETX is very dependent on the DOS version; witness the many versions such as NET3, NET4, NET5, and so on. DOS 6.0 uses the SETVER command to tell NETX that it's supposedly running under DOS 5.0.

One of Novell's goals for NetWare 4.0 was to make the workstation code itself more modular. Just as there are NLMs on the server side, NetWare 4.0 introduces Virtual Loadable Modules, VLMs, on the client side. A VLM is something like a dynamic link library, a module that can be loaded and unloaded depending upon what functionality a user needs. A VLM developer's kit is available from Novell developer services in Austin, Texas.

NetWare 4.0 includes a NETX VLM module, which provides backward compatibility with shell and front-end requests. However, this is only loaded optionally for applications that specifically require it. The required module is REDIRVLM, which uses standard INT 2Fh DOS redirector.

Since this is a redirector there's not much more we need to say about it here. Chapter 8 discusses this DOS standard at length. Whereas a front-end requestor such as NETX/VLM intercepts DOS and all the undocumented DOS services such as the CDS and SFT, a redirector is built-in part of DOS. Instead of hooking INT 21h, a redirector is *called* by DOS. DOS passes it all drives, whether local or remote, to be processed through the CDS. It is up to the redirector whether local or remote. Because a redirector doesn't bypass these DOS data structures, programs such as ENUMDRV wouldn't need to be rewritten for NetWare 4.0 (although of course one might still want to know the NetWare version of the underlying file server software).

On the other hand, NetWare's new workstation client code is a 100% redirector. Novell implements the INT 2Fh redirector interface but provides no hooks for INT 21h events. No VLM is loaded. Novell must emulate those old INT 21h services NetWare clients use such as the INT 21h AH=E2h interface (see below). Novell's engineers stuck a INT 21h broker on the bottom of, of course, to one of the unpopular INT 2Fh interfaces: a Redirector. The new DOS client, which is both a Shell and a Redirector, is called the Novell DOS Requester.

You might wonder how a redirector-based NetWare client can support the legacy NetWare drives through Z? 32 drives in DOS? DOS uses LASTDRIVE=Z as the maximum drive letter. A Novell README.VLM file mentions somewhat cryptically that "DR DOS could be enhanced to allow these drives to be treated as local by providing a new option for the LASTDRIVE parameter in CONFIG.SYS, for example, LASTDRIVE=32." Naturally MS-DOS could be enhanced. Microsoft decides to adopt any changes made to DR DOS." Of course we could also hack the NLASTDRV utility from Chapter 2 in this way.

On the other hand, perhaps the NetWare drives A:–Z: aren't that important. Novell has always intended these drives for internal use by programs that need to run portable ways rather than not generally for end users. Novell has long warned developers that the temporary drive mappings

[illegible] place. Novell suggests using direct Universal Naming Convention (UNC) see Chapter 8) server and path designations. For instance, rather than mapping drive "F:" to "\\NETSYSMYSERVER\SYS", if you're accessing a file temporarily, you can instead access them using the path "\\NETSYSMYSERVER\SYS". Direct connectivity is available in NETX, though apparently with some problems in some DOS functions, notably Rename.

How NETX Changes INT 21h

We've seen that NetWare adds many functions to the INT 21h interface. Novell documents some of these, and others are undocumented but well known through disassembly or through inspection of [illegible] source code to NetWare C Interface Library. Because the NetWare extensions to INT 21h are [illegible] topic, we'll look here at what changes NetWare makes to the standard INT 21h functions. In following discussions, I base information mostly provided by [illegible] Novell documentation. Most of NETX's changes to INT 21h entail disappearing, redirecting, and [illegible] the techniques discussed in greater detail in Chapter 6.

One result of NETX's modifications to INT 21h is that it disappears in the NetWare 4 [illegible] environment. Instead, redirection is established by hooking INT 21h in order to [illegible] NetWare services via INT 21h subfunction F2h, the interface. The interesting question then is [illegible] NetWare 4 will achieve the same results that NETX does for the DOS redirector. We'll look briefly at this topic.

NETX.COM hooks INT 21h and goes to work on behalf of almost every single DOS function [illegible] NETX does this because there are fewer functions that NETX *doesn't* change than to enumerate all the ones it changes. The following are the only INT 21h functions that NETX does not specially use: 00h, 1Bh, 1Ch, 20h, 24h, 2Ah, 30h, 32h, 34h, 35h, 37h, 38h, 59h, 5Ah, 5Bh, 5Dh. NETX passes all other DOS functions on to DOS unchanged. For example, NetWare intercepts all the I/O and directory calls, with those intended for NetWare file servers turned into NCP requests, as described above[4]. This is [illegible] NetWare [illegible] operates DOS, a chapter on other DOSs. NETX replaces so much of DOS that its [illegible] NetWare, so if you are effectively running under [illegible] DOS. Internally, NETX intercepts various INT 21h AX = 1A00h to determine if they are [illegible] NetWare, but sets no network shell [illegible] PSP:[0Ah] as I'll do in Listing 4-4 below.

By far the greatest [illegible] of some of NETX's mechanisms, are the changes that NETX makes to the DOS INT 21h interface:

- *Specific Standard Handle Redirection.* INT 21h functions 01h, 02h, 06h, 07h, 08h, 09h, 0Ah, 0Bh, 0Ch, 3Fh, 40h, 44h, 4Ah, 4Bh, 54h, 5Eh, 5Fh, 62h, 63h, 65h, 66h, 67h, 68h, 6Ah, 6Ch. Even though DOS [illegible] I/O, NETX needs to see if there has been redirection to or [illegible] NETX's own [illegible] (LOGIN, CAPTURE, ATTACH, etc.). LOGIN is a program that calls NetWare API functions, sending and receiving data to a NetWare file server. If there's redirection of standard handles, NETX temporarily substitutes a device that routes the I/O to a "NETWARE" device that handles the redirection.
- *Network Drive Detection.* INT 21h AH=19h, which we looked at in Chapter 2. Whereas [illegible] DOS returns the LASTDRIVE value, NETX always returns 32, representing the [illegible] NETX then [illegible] described above, with the actual number of local drives as [illegible] NetWare. INT 21h AH=19h, see Listing 2-19 in Chapter 2. As a sample of the NetWare code, Figure 4-2 shows the NETX handler for INT 21h AH=0Eh.

Figure 4-2: NETX Handler for INT 21h AH=0Eh (Select Disk)

```
4491:1BD6   SEL_DISK_0E
4491:1BD6       push es
4491:1BD7       cmp dl,20h              ; drive >= 32?
4491:1BDA       jae PASS_0E_TO_DOS      ;   yes, chain to previous INT 21h
4491:1BDC       mov bl,dl               ;   no  put drive # into BX
```

```
4491:18DE       xor bh,bh
4491:18E0       test cs:DRV_FLAG_TABLE[bx],83h      ; is it a NetWare drive?
4491:18E6       jz PASS_DE_TO_DOS                   ; no  chain
4491:18E8       mov cs:CURR_DRV,dl                  ; yes  set NETX curr drive
;     some NetWare TASK stuff
4491:1C04   PASS_DE_TO_DOS:
4491:1C04       pop es
4491:1C05       pop bx
4491:1C06       pushf
4491:1C07       call cs:INT21    ; chain to previous INT 21h
4491:1C0C       mov al,20h       ; force 21/0E return LASTDRIVE=32 (20h)
4491:1C0E       iret
```

- *Delete Inhibit*: INT 21h functions 13h, 41h, and 56h allow read-only files to be deleted; using the FCB delete call, NetWare does not allow this.
- *Set Interrupt Vector*: INT 21h function 25h. NETX substitutes INT 24h vectors for handlers in place of COMMAND.COM's so that network errors are not intercepted. However, with the DOS Redirector, NetWare 4.0 NETX no longer substitutes its own INT 24h handler; instead, NetWare provides extended error messages through the INT 21h AH=59h call that COMMAND.COM makes to obtain extended error information. See Table 6-8 in Chapter 6.
- *Parse Filename*: INT 21h function 29h. DOS uses a default drive number if the drive number is specified as 0. NETX substitutes the user's default drive number, which is set to correspond to the network drive on which NETX maps the user's home directory and PUBLIC directory. Applications attempting to build a configuration file in the user's home directory rely on this NETX feature.
- *EXEC*: INT 21h function 4Bh. When a program is loaded and executed and about to stop, DOS passes the segment address of the environment block which NetWare uses to locate the NETX.COM file. NETX then installs its INT 24h handler and sets the Drive Get/Set Default Drive Number (INT 21h AX=4400h, 4700h) function to DOS. See the NETVER listing in the *DOS Internals* chapter. See Table 6-8 in Chapter 6 for specifications that Novell NETX uses for the 21 4B05 call. NETX uses the Microsoft network pipes interface via the share.exe interface to provide support for Microsoft Windows for Workgroups peer-to-peer networking.
- *Set PSP*: INT 21h function 50h. NETX changes DOS's internal idea of the PSP address (0034 under DOS 3.x, 0032 under DOS 4.x). See Chapter 6. Windows 3.1 applications use this function to find the PSP and then look at offset 16h to find the parent PSP. Undocumented NETX uses AX=DC01h to get the current value of the network connection number. See *Undocumented NetWare*, Addison-Wesley, 1994. NETX saves the current DOS PSP in the first word of the NETX.COM file. NETX saves this PSP then sets the current PSP to zero. NETX changes the value to 0C01h and then restores the original PSP. Novell NetWare 3.11 SHELL.CFG option SET PSP=0 causes the PSP to be set to zero. Some programs, such as Novell's 2 to MF 50h, set the PSP to zero. NETX keeps track of the current PSP in order to restore it when the program terminates. NETX keeps a stack of PSPs (0000:0D3Eh) and Novell's SHELL.CFG option STACKS=n changes the number of stacks. Novell NetWare 3.11 SHELL.CFG option SET STACKS=n changes the number of stacks. NETX hooks INT 0Bh, which is the DOS hardware interrupt.

Microsoft C Warranties and SetPSP(0)

Who, you might ask, would do a Set PSP of zero? Why, Microsoft, of course! Some releases of Microsoft QuickC, Programmer's Workbench (PWB), and Microsoft C 6.0 Setup contain a DOS detection function that tests for the presence of "genuine" MS-DOS by calling INT 21h AH=50h to set the PSP to 0, then checking the current psp field in the SDA (see Chapter 6, to see if it has become set to 0. Microsoft's code then does the same thing

with a PSP of 0FFFFh (-1). Running these versions of the C compiler under NetWare thus trashes not only the INT 0Fh vector, but also some other location that depends on whether the A20 line is enabled. If A20 is off, FFFF:003E wraps around to 0000:002C, which holds the INT 0Bh vector. COM2 uses INT 0Bh. Imagine someone's surprise when, after compiling a program with QuickC under NetWare, their communications package fails! The DOS world is a constant reminder of how "too many cooks spoil the soup" is full of interesting interactions like this. It almost makes you wish that Microsoft had even more of a monop-oly.

We had heard rumors that QuickC performed such a test, but found it so difficult to believe we had to check it out for ourselves. Digging out a copy of version 2.51 of the Microsoft C compiler with QuickAssembler, we found that the QuickC README.DOC file actually refers obliquely to this test, saying that the product "prints a warning message when a non-standard version of DOS is detected. The /nologo option prevents this message from being printed." Indeed, QC.EXE (dated April 6, 1990) contains the following message, which is strangely reminiscent of some of the unfair trade practices explicitly banned by the Clayton antitrust act:

```
WARNING: This Microsoft product has been tested and certified for use
only with the MS-DOS and PC-DOS operating systems. Your use of this
product with another operating system may void any usable warranty
protection provided by Microsoft on this product.
```

Remember, this message is coming from a Microsoft C compiler, not from part of MS-DOS. It's no wonder that shortly after bringing this warranty-related warning message to the attention of an attorney at the U.S. Federal Trade Commission (FTC), one of the authors started hearing rumors that the FTC's consumer affairs bureau had suddenly become involved in the investigation of Microsoft, and that the Magnuson-Moss Warranty Act had entered the picture.

While it's a good thing that this message can be turned off, what about those calls to Set(PSP:0) and Set(PSP:1)? Recall that, when this code was written, the Set PSP function was barely documented, yet Microsoft's C compilers compete with products from other vendors. Using whether Set PSP modifies a certain fixed spot in the DOS data segment is just the sort of underhanded use of insider knowledge that Microsoft applications are not supposed to be taking advantage of—particularly when the sole purpose of this code is to make Microsoft C users think they shouldn't run versions of DOS other than Microsoft's. You could make a good case that it's dumb to bother with anything except genuine MS-DOS, but it's inappropriate, and possibly even restraint of trade, for Microsoft's C products to try to convince you of this point.

To see if QC.EXE actually includes such code, we first ran it under the following INTRSPY script:

```
; psp0.scr
intercept 21h
    function 50h on_entry
        if ((bx == 0) || (bx == 0FFFFh))
            output "SET PSP " bx " from " CS ":" IP
```

Sure enough, INTRSPY produced the following output, indicating that the current PSP was being set to 0 and -1 (FFFFh):

```
SET PSP 0 from 9E33:D16F
SET PSP FFFFh from 9E33:0177
```

Using the CS:IP addresses the NTRSPY script displays, we used WINICE to disassemble the code. Figure 4-3 shows the results.

Figure 4-3: Microsoft QuickC DOS Detection Code

```
u 89e33:014e
; this is in the middle of some sort of "is dos okay?" function
9E33:0000014E   MOV     AH,52
9E33:00000150   INT     21              ; get DOS DS into ES; ignore BX
9E33:00000152   MOV     AX,ES:[0004]    ; DOS_DS[4] = SDA type
9E33:00000156   CMP     AX,0001
9E33:00000159   JA      0180            ; hmm, DOS DS[4] > 1 is ok, DOS 2?
9E33:0000015B   SHL     AX,1
9E33:0000015D   MOV     SI,AX           ; AX is 0 or 2
9E33:0000015F   MOV     SI,[SI+0134]    ; QC knows CURR_PSP ofs in DOS_DS
9E33:00000163   MOV     AH,51           ;    [134h] = 020E, [136h] = 0330h
9E33:00000165   INT     21
9E33:00000167   MOV     DX,BX           ; save current PSP in DX
9E33:00000169   XOR     BX,BX           ; BX = PSP = 0
9E33:0000016B   MOV     AH,50
9E33:0000016D   INT     21              ; SetPSP(0)
9E33:0000016F   CMP     ES:[SI],BX      ; see if DOS_DS[CURR_PSP] matches
9E33:00000172   JNZ     0183            ;    no: not MS-DOS
9E33:00000174   DEC     BX              ; BX = PSP - 1
9E33:00000175   INT     21              ; SetPSP(PSP-1)
9E33:00000177   CMP     ES:[SI],BX      ; see if DOS_DS[CURR_PSP] matches
9E33:0000017A   JNZ     0183            ;    no: not MS-DOS
9E33:0000017C   MOV     BX,DX
9E33:0000017E   INT     21              ; restore PSP
9E33:00000180   JMP     01BC
9E33:00000182   NOP
; not_msdos
9E33:00000183   MOV     BX,DX           ; problem, no match
9E33:00000185   INT     21
9E33:00000187   XOR     AX,AX           ; return false = 0
9E33:00000189   JMP     018F
9E33:0000018B   NOP
; is_msdos:
9E33:0000018C   XOR     AX,AX           ; ok: match
9E33:0000018E   DEC     AX              ; return true = -1
; done:
9E33:0000018F   POP     ES
...
dw 89e33:0134 0130
9E33:00000134   020E  0330
```

This code definitely is taking advantage of inside knowledge and is using a narrow definition of DOS compatibility. For example, QuickC wants to find the address of the current psp held in the DOS data segment. While also undocumented, the common way to get this in third party code would be to call INT 21h AX=5D06h to get a pointer to the Swappable Data Area and then look at offset 10h. Instead, the code calls INT 21h AH=52h to get the DOS data segment into ES (ignoring the SysVars offset in BX), then uses a little known value at offset 4 in the DOS data segment to determine whether there is a DOS 3.0 style SDA or a DOS 4.0-style SDA. Based on this, the program uses hard wired offsets for the current PSP in the DOS data segment (offset 02DEh in DOS 3.0 and offset 0330h in DOS 4.0 and higher).

Despite the supposed "separation of church and state" between applications programmers and operating systems programmers at Microsoft, the use of DOS DS:4 reveals an intimate knowledge of the DOS code. Unlike many other features of undocumented

DOS which are open secrets, the SDA type indicator at DOS DS[4] has not been publicized at all. To our knowledge, the only place this has been discussed in print has been in the writings of Geoff Chappell (see the discussion of "Direct Access to Kernel Data" in Chapter 13 of his *DOS Internals*). The code for SHARE and other DOS utilities relies on DOS DS[4], but it is certainly odd to see it showing up in the code for QuickC, which is an application, and doubly odd to see it being put to such seemingly malicious use.

Listing 4-4 shows a short C program, PSPTEST.C, that duplicates the nasty QuickC code. Of course, PSPTEST first checks to see if NETX is running, and if it is, PSPTEST asks the user if they really want to run the test, since SetPSP(0) under NETX may corrupt their system.

Listing 4-4: PSPTEST.C

```
/*
PSPTEST.C
Andrew Schulman, June 1993
From Undocumented DOS, 2nd edition (Addison-Wesley, 1993)
*/

#include <stdlib.h>
#include <stdio.h>
#include <ctype.h>
#include <conio.h>
#include <dos.h>

#ifndef MK_FP
#define MK_FP(seg, ofs) \
    ((void far *) (((unsigned long) (seg) << 16) | (ofs)))
#endif

typedef int BOOL;
typedef unsigned char BYTE;
typedef unsigned short WORD;

#pragma warn -rvl
WORD _dos_getpsp(void)
{
     asm mov ah, 51h
     asm int 21h
     asm mov ax, bx
}

void _dos_setpsp(WORD psp)
{
     asm mov bx, word ptr psp
     asm mov ah, 50h
     asm int 21h
}

#pragma warn -rvl
WORD _dos_getds(void)
{
     asm mov ah, 52h
     asm int 21h
     asm mov ax, es
     // ignore SysVars offset in BX
}

// Novell Return Shell Version function (INT 21h AH=EAh AL=01h)
// see INTRLIST on accompanying disk, also see Barry Nance,
//  Networking Programming in C, pp. 117, 361-2.
BOOL netware_shell(void)
{
    char buf[40];
    char far *fp = buf;
    asm push di
    asm mov ax, 0EA01h
    asm mov bx, 0
```

```
    _asm les di, fp
    _asm int 21h
    _asm xor al, al
    _asm mov ax, bx
    // if BX still 0, then NetWare not present, return in AX
    _asm pop di
}
void fail(const char *s) { puts(s); exit(1); }
main()
{
    BYTE far *dos_ds,
    WORD far *curr_psp_ptr,
    WORD psp,

    dos_ds = (BYTE far *) MK_FP(_dos_getds(), 0),
    switch (dos_ds[4])
    {
        case 0   curr_psp_ptr = (WORD far *) (dos_ds + 0x0D0E), break,
        case 1   curr_psp_ptr = (WORD far *) (dos_ds + 0x0330), break,
        default: puts("DOS_DS[4] > 1"); goto okay;
    }

    if (netware_shell())
    {
        puts("Under NETX, SetPSP(0) can corrupt your system  "),
        fputs("Still want to continue? [Y/N]  , stdout),
        if (toupper(getch()) != 'Y') fail( \nbye ),
        putchar('\n'),
    }

    psp = _dos_getpsp(),
    if (*curr_psp_ptr != psp)
        fail("Curr_PSP field wrong!"),

    _dos_setpsp(0),
    if (*curr_psp_ptr != 0)
    {
        _dos_setpsp(psp),
        fail("SetPSP(0) test failed");
    }

    _dos_setpsp(-1),
    if (*curr_psp_ptr != -1)
    {
        _dos_setpsp(psp),
        fail("SetPSP(-1) test failed");
    }

    _dos_setpsp(psp),
    puts("SetPSP(0) and SetPSP(-1) tests succeeded")
okay:
    return 0,
}
```

It's worth noting that this program succeeds, not only under MS-DOS 3.0 and higher, but also under DR DOS 5.0 and higher. In other words, DR DOS keeps the current PSP at exactly the same location, DOS DS[02DEh], as DOS 3.0 does. What a coincidence!

PSPTEST also succeeds under the old Concurrent DOS 386 2.01, which doesn't implement the DOS DS[4] flag. QuickC also runs in this environment. If you examine the code, you will notice that any environment with DOS DS[4] > 1 is okay; presumably this is because QuickC has to run on DOS 2.x, which didn't implement the DOS DS[4] flag. In

fact, it's unclear under what circumstances you would have a DOS clone in which (DOS DS[4] == 0 but DOS DS[2DEh] != CURR PSP) or (DOS DS[4] == 1 but DOS DS[330h] != CURR PSP)

In summary, the SetPSP(0) code seems to package up all the problems of undocumented DOS in a nutshell: we have NetWare hijacking unused fields in the PSP (or perhaps not, see below), NetWare failing to think through all the implications of hooking INT 21h, Microsoft applications accessing undocumented DOS kernel data, and Microsoft applications testing for the presence of non-Microsoft operating systems in what certainly looks like a subversive arrangement (see Chapter 1).

What about that Novell task ID? According to an engineer at Novell, NetWare uses this ID to keep track of multiple processes running on a single workstation. Just to make things interesting, this task ID is apparently reserved for Novell *and Microsoft*. Microsoft's source file for the PSP ([DOS]\inc\DOSMAC.INC, adaptation for OS/2 2.x; see Chapter 6) contains a "PDB Novell task ID" field, and the comment says Novell NetWare uses these. The task ID starts at 1 for the master copy of COMMAND.COM, and increments for each task loaded that does DOS I/O. Some programs are even associated a task ID by NETX:

- *IRETX call*. INT 21h function 0DBh. NETX hooks the IRETNAME function, and uses it to return a UNC server/volume path name. Thus you can call IRETNAME to get the underlying server and volume name for a NetWare drive.

Aside from these NETX modifications to INT 21h, basically present us with a different version of DOS. On the other hand, these modifications go as far as starting at NetWare 4.0.

Undocumented NetWare

NetWare has a vast amount of undocumented functionality—enough to fill an entire book. As noted earlier, Peter Dyson's *Undocumented NetWare* is scheduled for publication in 1994. In the meantime, it is interesting to consider the following:

- NetWare *runs on* a DOS physical file system used on NetWare file servers is proprietary, which makes it difficult to write a utility such as Norton Utilities or PC Tools for NetWare file servers. Novell can, however, license a developer to write a NetWare file system.
- The *undocumented NETX* calls mentioned above appear in the Watcom linker that Novell ships. Many of these calls are used to build an IPX packet for broadcasting. These calls would be useful for writing network diagnostics or utility vendors interested in custom backup, server activity software, and the like.
- NetWare *Lite*. The API for NetWare Lite appears to be completely undocumented. The Interrupt 2Fh AX=1200h multiplex check for NetWare Lite functions, such as NI 2Fh AX=1200h installation check and LAN@0800h SERVER.EXE installation check. (Dos may all change with Version NetWare 4.0, which is slated for the next release of NetWare Lite. The server component of NetWare Lite is based on the NCP protocol of NetWare 286 on the special Lite protocol, which means it will work with the VLM-based common client for DOS being shipped with NetWare 4.0. Currently, you must load separate workstation software for NETX to be a NetWare client and LITENETX to be a Lite client. With the common client you will be able to use one TSR instead of two. Rumor has it that Novell DOS 7.0 will virtually incorporate Personal NetWare for DOS and that the peer-to-peer server will use DPMS.
- The NetWare Core Protocol. Novell considers NCP "proprietary." While NCP is immediately available to anyone with a network sniffer such as General Software's The Snooper or even

Now I own LANalyzer. Novell has never publicly documented the protocol. A partial discussion appears in *Novell's Guide to NetWare LAN Analysis* by Laura Chappell and Dan E. Hakes, Novell Press, 1993. (General Software's Fox Stopper comes with full C source code, including an NCP module.) For more information on NCP, see Dave Novarro's article, "Novell's Unclean Hands—The NetWare Core Protocol (NCP)," *Dr. Dobb's Journal*, November 1993.

- *The I2 interface.* As noted earlier, NETX extends INT 21h to provide many NetWare-specific functions. While Novell documents many of the extensions, some (and even INT 21h AH=E2h) are not documented. Also, it allows programs to send raw NCPs to the file server. I2 isn't critical to issuing raw NCPs as the O'Hara/Gursha article cited above notes, you can directly use IPX. A friend at Microsoft complains, "All they had to do was publish the bloody Int 21 stuff. They've already documented it, although they have removed a few code fragments that enable use the interface. This was a response to developers who were explosive deleted from the code just to do something that some Novell utility could do. However, Novell does seem committed to supporting I2 and has provided attendees of its BrainShare developers conference with information on the interface, though at the same time keeping NCP information without which I2 is useless under wraps. An engineer at Novell supplied the following information on the I2 interface:

```
RawNPRequest          ;242 (F2)
** undocumented **
Generic function used to send raw NCP requests.  Documented in part
by the Erase Files function for purging files (INT 21h AX=F244h)
Input:
    AL      NCP function request code
    DS:SI   Request List
    CX      Request Length (in bytes)
    ES:DI   Reply List
    DX      Reply Length (in bytes)
output:
    AL  Return code
```

Other undocumented INT 21h calls include AttachHandle (AH=B4h), an interface Novell provides to give DOS full access to NetWare files (including on Macintosh OS/2 and UNIX), GetData (AH=B5h), which provides data for the VSHELL/WARP 386 Windows VxD, a set of functions (AH=B8h) used to get instance data, scan and edit virtual machines and so on—but Ralf Brown's interrupt list notes AH=B8h is used to edit the master environment "COMSPEC" and "PATH" parameters.

The function to edit the master environment is interesting given the difficulty discussed in Chapter 10 of building the master environment. According to an engineer at Novell, they reverse-engineered out of the Spontaneous Assembly product, as their code seemingly works best. Novell changes the PATH when you log in to include your search drives in the list. Obviously, to make this change, Novell must find the master environment. According to one user, this makes for some real nastiness if you try to LOGIN to Novell while shelled out of another program. So now Novell is providing an undocumented way to let other programs set NetWare find the master environment block for them.

OS/2 2.x: "A Better DOS Than DOS"?

When OS/2 1.0 first appeared in 1987–88, Microsoft and IBM, along with many PC software developers, thought OS/2 would replace MS-DOS and take over the desktop. OS/2 1.x had a great DOS compatibility box, commonly referred to as the DOS compatibility box or Control Program (CP), which ran some DOS software and on which much work was spent. But it's unfortunate that most of

[illegible] would fade away as all DOS programs were flushed out of circulation and replaced by new OS/2 programs.

[illegible] IBM [illegible] ceased to be the most important force in the software [illegible] Windows and it became clear that OS/2 would [illegible] DOS. In fact [illegible] OS/2. However, OS/2 2.0 [illegible] Software Products [illegible] IBM [illegible] as a separate company [illegible] improvements [illegible] DOS [illegible] that IBM [illegible] OS/2 provides a better DOS than DOS."

[illegible] OS/2 2.x provides [illegible] preemptive multitasking DOS [illegible] Virtual DOS Machines (VDM) [illegible] DOS [illegible] DOS [illegible] Windows [illegible] and Windows NT [illegible] DOS and DOS [illegible] V86 [illegible] mode of the 80386 and higher processors, rather than in real mode.

[illegible] V86 [illegible] DOS [illegible] is possible [illegible] better DOS than DOS is [illegible] V86 DOS [illegible] better than DOS itself. But [illegible] DOSSPEED [illegible] Chapter 3 that V86 DOS [illegible] DOS [illegible] IBM [illegible] DOS sessions [illegible] DOS [illegible] Fortunately, Intel's new [illegible] processor has [illegible] V86 mode [illegible] improve performance by reducing the number of [illegible] "Undocumented Pentium," below.

Undocumented Pentium

Intel's Pentium processor, commonly known as the 586 or P5, includes enhanced [illegible] virtual 8086 mode that will improve performance by reducing the number of [illegible] programs running in V86 mode trap to the protected-mode V86 monitor. The VME [illegible] the new CR4 control register enables these enhancements, which include the new Virtual Interrupt Pending (VIP) and Virtual Interrupt Flag (VIF) bits in the Pentium EFLAGS register.

Unfortunately, Intel's *Pentium Processor User's Manual* provides no further information [illegible] these important-sounding enhancements to V86 mode. Appendix H, "Advanced Features," says that such information is "considered Intel confidential and proprietary and have not been documented in this publication. This information is provided in the *Supplement to the Pentium Processor User's Manual* and is available with the appropriate non-disclosure agreement [illegible]." According to Spencer Katt's occasionally reliable "Rumor Central" [illegible] Week (May 24, 1993), the length of the NDA is fifteen years!

[illegible] the VIF bit in EFLAGS is intended to eliminate the need for trapping into protected mode every time a program running in V86 mode executes a CLI or STI instruction. Having to maintain a virtual interrupt flag has been one of the most serious performance problems with V86 mode. According to the DPMI specification, "Since *cli* and *sti* are privileged instructions, they will cause a protection violation and the DPMI provider will simulate the instruction. Because of the overhead involved in processing the exception, *cli* and *sti* should be used as little as possible. In general, you should expect either of these instructions to require at least 300 clocks." 300 clocks! The new VIF bit in EFLAGS sounds like an excellent idea.

According to *Microprocessor Report* ("Intel Reveals Pentium Implementation Details," March 29, 1993), the infamous Appendix H "is supplied only to selected operating-systems

vendors." Presumably users of V86 mode, such as Microsoft, IBM, Novell, Qualitas, and Quarterdeck, will have no trouble getting their hands on the necessary documentation from Intel and incorporating these Pentium enhancements into their software. Then it will just be a question of when end users actually get machines with Pentium processors!

There are many interesting and important aspects to MVDMs in OS/2 2.0. Here, however, we focus exclusively on how well OS/2 emulates MS-DOS, emphasizing, of course, its support for undocumented DOS functions and data structures. For more information on MVDM technology, see the chapter on compatibility in Harvey Deitel and Michael Kogan's *The Design of OS/2*. Addison Wesley, 1992.

MVDMs and VDDs

OS/2 MVDMs operate a lot like DOS boxes in Windows Enhanced mode. In both environments, DOS programs make normal INT 21h calls and INT 21h calls do. INT 10h calls support read and write memory operations, but for the most part, DOS programs look for A virtual machine monitor catches these events and hands them off to various device drivers. VxDs in Windows but implemented as VDDs in both OS/2 and Windows NT, which virtualize whatever device the DOS program thinks it's directly banging on.

These devices aren't necessarily pieces of hardware. For example, just as Windows has the V86MMGR VxD to emulate the XMS and EMS specifications (that's right, XMS calls in Windows aren't handled by EMM.SYS), V86MMGR emulates XMS. In OS/2 2.x, however, you don't use EMM.SYS or an EMM driver; instead, you use VDDs VXMS.SYS and VEMM.SYS. In OS/2 2.x, VDPMI.SYS provides the DOS protected mode interface, VDD.SYS provides optional protected mode INT 21h services, and DOSMGR.SYS emulates Windows.

Of course, some VDDs in OS/2 2.x do some VxDs in Windows do. For example, there's VPICD.SYS, which is VPICD in Windows; VMOUSE.SYS, VMD, VKBD.SYS, VKBD, and so on. There are many similarities in Windows Enhanced mode and down to the details of how virtual devices are used. Windows VxDs use the undocumented Device Control Procedure. The difference is that OS/2 VDDs use the INT 2Ah hook, which is a hooked version of the INT 2Ah that's partially documented in INT 86(1) in the OS/2 2.x SDK CD-ROM. VDDs in OS/2 2.x look like VxDs in Windows 3.x Ring 0 protected mode and NT VDDs when we see them in Ring 3 kernel mode.

DOS applications support OS/2 services extensible through VDDs in the same way that VxDs can provide services to protected-mode programs running under Windows. To intercept software interrupts, a VDD in OS/2 can hook the V86 DOS processor just as VxDs in Windows can call services from VMM or other VxDs. OS/2 VDDs have a client-based set of Virtual Device Helper (VDH) functions. For example, VxDs can hook V86 interrupts with VDHInstallIntHook and protected-mode interrupts with VDHInstallPMHook. Other DOS programs I/O ports can be virtualized with VDHInstallIOHook. The *OS/2 2.0 Technical Library Device Reference* (IBM, available on MSDN) documents these VDH functions, and the VDD chapter of Steven J. Matthews's book *Writing OS/2 2.0 Device Drivers* does, too.

All this is very similar to VxD programming in Windows Enhanced mode. This is not surprising since Microsoft and IBM wrote the code for the IBM Microsoft device. When Microsoft teaches OS/2 in public, its most exciting demo is how easy it is to port VxDs to VDDs.

But there are several critical differences between OS/2 MVDMs and Windows Enhanced mode. We saw in Chapters 1 and 3 that Windows reflects many DOS calls down to MS-DOS in V86 mode. But in OS/2 *DOS is a task*. This is a rather obvious point, but it bears repeating. OS/2 does not run on top of DOS; DOS is nowhere in sight. Any INT 21h calls that a DOS program makes under OS/2 must be handled by OS/2 itself. Windows, at least around V3.1, has the

I/O calls is wrong, a little API translation and then calling down to DOS in V86 mode. But OS/2 ... DOS ... calls intercepts to the OS/2 kernel. For example, INT 21h AH=3Dh calls ... DosOpen ... function. AH=3Eh must be handled by DosRead ... and so ...

... DOS programs running under OS/2 really do think they are running under a version of DOS. The undocumented, undocumented INT 21h functions and many of the standard ... functions ... can make an INT 21h AH=30h call and get back a DOS version number.

So What Version of DOS Is This DOS Emulation Pretending To Be?

... OS/2 2.0 INT 21h AH=30h returns 0014h (DOS 20.00) and OS/2 2.10 returns 0A14h (DOS 10.10). ... OS/2 ... OS/2 ... DOS box ... OS/2 2.1 ... proclaimed itself to be DOS 10.10. ... Logic ... suggests that ... DOS ... *should* be a genuine DOS, OS/2 ... compatibility ... MS DOS 6.0 ... generation version number increases and ... MS DOS 7.0 on the horizon. It seems possible that ... DOS 10.0 ... 2000 ... at least does seem a bit incongruous. Actually, one of our ... As we ... MS DOS ... 10.0 ... at SETVER ... and only handle ... 9.99. ... MS DOS has no plans to ever reach DOS 10.

... No ... version ... is ... for telling DOS applications that they are in fact running under OS/2 ... which MS DOS version's OS/2 ... functions ... from INT 21h AX=3306h. ... MS DOS V ... set ... BH ... the same value as INT 21h ... which ... expression ... function 3306h, which came ... with DOS 5.0. It's as ... OS/2 ... emulating ... MS DOS 5.0 ... higher ... doesn't ... there's no ... to get the emulated DOS version. An engineer at IBM reports that

> ... OS/2 ... DOS ... was ... and ... of DOS 3.3 ... added ... work removing ... OS/2 2.0 ... pretend ... DOS 5.0. We ... at the ... functions specifically ... DOS ... and DOS ... things ... Dos ... and ... related ... functions. Most ... the ... compared ... but ... one ... was the ... command. ... is a simple ... of ... and ... Let's look. When we ... this ... we noticed that there ... [illegible] ... now ... INT 21h ... was ... INT 21h AX=4400h and AX=4401h] ... version ... [illegible] ... DOS 5.0 ... [illegible]

... MS DOS's ... OS/2 ... MVDM ... fake DOS version numbers ... per ... basis ... specified ... DOS VERSION ... With DOS VERSION ... DOS 2.0 ... be told ... they are running under DOS 5.0 ... DOS VERSION ... the SETVER ... MS DOS ... DOS VERSION includes ... [illegible] ... to ... the ... DOS ... Appendix ... In ... versions of MS DOS 5.0 also ... SETVER. ... SETVER ... DOS VERSION ... nothing ... OS/2 ... DOS ... simply ... what ... INT 21h ... [illegible] ... application.

DOS VERSION ... settings ... OS/2 MVDMs. For example, DOS ... INTERLNK ... installable ... in a VDM, OS/2 does not use a Current ... Structure ... DOS ... OS/2 ... handles all INT 21h file I/O and ... DOS ... SYS ... OS/2 ... the same purpose as LASTDRIVE= in a DOS CONFIG.SYS ... OS/2 ... different. Multiple VDMs can run simultaneously, each with a different DOS LASTDRIVE.

... FILES ... OS/2 ... similar to the FILES= statement in DOS CONFIG.SYS. As ... Chapter 8, ... MS DOS FILES ... the size of the System File Table (SFT), ... handle ... MS DOS ... a file or ... program ... In Table 8-1, ... which in turn ... indexes ... file handle ... MS DOS ... But OS/2 MVDMs don't ... SFTs. While ... file handle is still an index into the

JFT the JFT holds OS/2 1x handles not SFT indices. From a DOS program's perspective, the SFT under OS/2 1.x can be much greater than 255 entries. Thus changing the SFT size is meaningless in an OS/2 VDM. What DOS FILES does then is increase the size of the VDM's JFT, using the OS/2 DosSetMaxFH function, which is similar to INT 21h AH=67h in DOS.

Another example is DPMI. DOS API, which controls whether the DOS Protected Mode Interface provided by the MVDM should support DOS client protected mode. As we saw in Chapter 3, DPMI and protected mode INT 21h are actually separate services. WIN-OS/2 supports both DPMI and DPMI DOS API, so applications such as Borland C++ 3.1 can interpret the presence of DPMI to mean that protected mode INT 21h is automatically available.

There's nothing special about these settings; they are simply registered per-process VDDs using documented VDH functions. See "Registering OS/2 DOS Settings" below. For example, VDPX.SYS registers DPMI_DOS_API, VMOUSE.SYS registers DOS_LASTDRIVE, and DOS_FILES and DOSKRNL registers DOS_VERSION. In a sense, these are not like SYSTEM.INI settings to Windows 3 started mode, which an VDD is used to establish.

Registering OS/2 DOS Settings

There is a VDD call VDHRegisterProperty (yes, it's documented in the OS/2 DDK) to set up a DOS Setting. Any VDD, whether system supplied or user written, can register a property. One of the pieces of information you must supply is whether the property can be changed at any time or only before the VDM is created. DOS Settings can be viewed as similar to DOS CONFIG.SYS processing, except that in DOS, unlike with OS/2 MVDMs, none of the settings can normally be changed once the machine is up and running. (We've seen in other chapters, of course, how to modify LASTDRIVE by changing SysVars, or how to modify FILES by adding new tables to the SFT chain.)

The following minimal VDD demonstrates a user-written DOS Setting. It doesn't do anything but add GEORGE_FULK to your notebook for DOS settings. The two reserved fields are ready-case sensitive help, which correctly the current PMVDMP.DLL which runs the notebook, ignores them. The reader will not be surprised to learn that this code was supplied by George Fulk, an engineer at IBM who contributed much of the information on OS/2 MVDMs in this section. John Shaw, also of IBM, supplied additional information.

```
; GEO_FULK.ASM
 386P
;
ASSUME  CS:CSEG, DS:FLAT, SS:FLAT, ES:FLAT
CSEG    SEGMENT  DWORD USE32 PUBLIC 'CODE'
Validate proc   near
        xor     eax,eax
        ret
Validate endp
CSEG    ENDS
;
ASSUME  CS:CINIT_TEXT
DSEG    SEGMENT DWORD USE32 PUBLIC 'DATA'
PROPERTYNAME    db      GEORGE_FULK ,0
DSEG    ENDS
;
EXTRN   VDHREGISTERPROPERTY: NEAR
CINIT_TEXT      SEGMENT DWORD USE32 PUBLIC 'CODE'
_VDDInit proc near
        push    ebp
        mov     ebp, esp
```

```
;   === register the DOS setting
        push    offset FLAT:PROPERTYNAME
        push    0       ;reserved
        push    0       ;reserved
        push    0       ;=boolean
        push    0       ;="other", non-system VDD
        push    1       ;=only change before VDM creation
        push    0       ;=default value, =off
        push    0       ;no range checking for boolean
        push    offset FLAT:Validate
        call    VDHREGISTERPROPERTY
        or      eax,eax                 ;if VDH called fails,
        jz      short InitDone          ; then fail the VDD init.
        dec     eax                     ;init!=0 means success
InitDone                                ;init==0 means failure
        leave
        ret
_VDDInit endp
;
CINIT   TEXT  ENDS
        END     _VDDInit
```

Loading a Genuine DOS

As [illegible] running DOS emulation OS/2 2.x can also load an actual copy of MS-DOS. The IBM *Installation Guide* has a paragraph titled "Running Specific DOS from Within OS/2 2.0" which [illegible] to start an actual copy of MS-DOS such as DOS LAN Requester that must run with an actual [illegible] copy of MS-DOS 4.0 or later. With OS/2 DOS emulation, the procedure involves [illegible] DOS boot diskette from [illegible] diskette image. [illegible] with the OS/2 VMDISK [illegible] the OS/2 kernel loads the OS/2 IFSHLP.SYS device, which allows the specific copy of DOS running in DOS box to access the OS/2 file system.

SYSLEVEL.DOS device driver that hooks INT 21h. How then does it communicate with the OS/2 kernel? Instead of INT 41h, it uses some calls to INT 06h with AX=xx and DS:pointing to a [illegible] VCOM, VDASK, or IFSHLP. However, this doesn't seem sufficient for a DOS device driver running in V86 mode to communicate with OS2KRNL running at Ring 0 in protected mode. IFSHLP uses HLT instructions to communicate with OS2KRNL. We asked one of the IBM MVDM engineers how this works.

> HLT is our magic privileged instruction. A Ring 0 instruction stops V86 mode, causes a Ring 3 exception. A part of OS2KRNL called EMV86 (emulate 8086) receives the exception, looks at the instruction, and the two bytes following the HLT to see if it's one of our special instructions and not a real HLT instruction. The code uses [illegible] to see where it is in order to find the address of the routine to call in OS2KRNL. Code [illegible] MVDM, part of OS2KRNL, knows all the valid calls.
>
> When a process in 8086 mode executes a new Ring 0 instruction, EMV86 emulates the 8086 instruction, passes the HLT instruction to the kernel MVDM, also part of OS2KRNL, to interpret the [illegible] and action. There is a second magic pair EMV86 uses in V86 mode to call VDD routines such as VRPI. IBMKRNL and IFSHLP use HLT.

Microsoft has hooks to Windows. Windows Enhanced mode uses VRPI for the same reasons as the latest V86 Local Port Emulation. Interestingly, if you see that DOS device drivers running under Windows NT use [illegible] to communicate with NTVDDs.

[illegible] OS/2 uses INT 41h to make an actual DOS or V86 mode emulating DOS is [illegible] running. Running an actual copy of DOS makes it more difficult to control pending in the DOS kernel as well as wastes resources. In addition, IFSHLP must catch DOS calls at a lower level than the normal DOS emulation code.

OS/2 2.x and Undocumented DOS

IBM's OS/2 2.0 *Compatibility Information* booklet, while noting that many DOS and Windows programs run under OS/2 2.0, notes however that "some applications do not because of their design or because they use undocumented system interfaces will not operate properly with OS/2 2.0."

As examples of DOS software that won't run, it lists "Better DOS than a DOS." IBM goes on to list "applications programs that directly address the physical sectors of OS/2 managed non-removable DASD" as other examples. (In other words, the Norton Utilities' "tuning sensitive" DOS programs.) VCPI clients (OS/2 *does* support the XMS, EMS, and DPMI specifications.) DOS debuggers that set 386 hardware breakpoints on 386 DR0-DR3 register access, and Windows programs that access VxDs. This includes any Win32s application since OS/2 can't load Win32s 386.

It's worth noting that more and more Windows applications require a VxD or Win32s. For example, Microsoft Visual C++ comes with three VxDs: CVW1386, DOSXNT386, and MMD386.INF. *Byte*, April 26, 1993, had an extremely confused discussion of OS/2's ability to run VC++, indicating that VC++'s need for VxDs was somehow "inexplicable." Attorneys at the FTC appeared at one point to interpret this to mean that VC++ perhaps required the VxDs simply to keep VC++ from running under OS/2. There is no evidence for this. CVW1386 is Nu-Mega's VxD for running the CodeView debugger on a single screen, and DOSXNT386 is used by the Phar Lap DOS extender used by the VC++ command line tools. It is why Windows applications won't run under OS/2 because the application requires a VxD. (It seems odd to IBM's responsibility either to write a VxD or later for WIN-OS/2 or to develop OS/2 VDD equivalents for the most important Windows VxDs.

OS/2 2.1 has improved support for DOS and Windows. You can launch DOS programs from WIN-OS/2, and Windows Enhanced mode is supported to the extent of running WINMEM32 applications. Still no VxDs however. Note incidentally that programs that require VxDs won't run under Windows NT either.)

On the question of running sensitive applications, one of the MVDM developers at IBM writes:

> As well as avoid DOS applications' use of slow services, we also wanted to avoid DOS applications' use of hardware. Hardware access by DOS applications is the root of MVDM. The only exception is for applications that require hardware capabilities beyond our capacity. For instance, we don't emulate every bug including I/O ports. As we saw it, we can only handle 1000 interrupts/second. Some applications want a serial port rate. One DOS app got data from a serial port at 19,200 interrupts/sec. We tried, but we could never obtain that rate. One vendor who I've received a lot of mail from is a DOS Netware program that uses control of a piece of hardware to create sessions. It uses serial I/O ports. No other sessions in the system, unless those I/O ports, but we could increase the interrupt rate dramatically.

It's important to know what kind of services a protected-mode DOS extender provides. One whole reason for these elaborate virtualization schemes is that popular PC applications bypass approved methods, making low-level calls instead of high-level ones, accessing I/O ports and memory locations instead of making DOS calls, and so on. This is necessary, as the DOS-level functions have room for improvement. The reason why these programs became popular in the first place. However, it also puts a great burden on the developers of environments such as OS/2, Windows NT, and Windows Enhanced mode.

If all applications played by the rules, it would be easy for DOS extenders. You wouldn't need all this elaborate device virtualization in the first place. Operating systems such as OS/2 could trap INT 21h and have all calls to it come to the INT 21h handler, everything could be done in a flat 32-bit mode. Virtualization, while impressive, hooking an I/O port just like it was an interrupt (amazing!), can lead to lower performance.

Given that so much low-level code is a fact of life in DOS software, let's focus on what support OS/2 provides for undocumented DOS. The following useful telegraphic summary comes from an engineer at IBM:

> We are supposed to support all documented INT 20h-21h calls and most of the undocumented ones too. We are close but not quite there. There are a couple of documented calls we don't have done yet. The undocumented ones are (as a wild guess) 50% here.
>
> Network redirectors, not yet.
>
> All internal data structures are the same as DOS 3.0 but some are read-only and others reserved. Entries placeholders. That doesn't mean that they are all used, just they have the same position and appearance. Many of the vectors are read-only.
>
> CDS is NUL terminated except for the INT 2Fh AX=1210h call which we take. Of course, no DOS 2 device driver in a CDS but we do not guarantee more on the DOS box.
>
> Current dir: MSCDEX. Nope. MSCDEX is a redirector. Note however that the VCDROM.SYS VDD for CD-ROMs does support the MSCDEX INT 2Fh calls.
>
> INRs work just fine. No known problems or restrictions.
>
> Floppy: DOS emulates normal work on diskettes, but not on the hard disk. No absolute sector reads/writes. INT 25h/26h not permitted on the hard disk. Unless an application issues an illegal call to hard disk, no DOS emulation, operating system can perform this.

In short, the OS/2 MVDMs provide a real-mode DOS that supports SysVars and SDA but no CDS or SFT and no network redirector. Running some of the programs from other parts of this book under OS/2 2.0 confirms this point:

- OKVAL (Chapter 2) works, so INT 21h AH=52h is supported, and SysVars has a valid LASTDRIVE value in the correct location.
- UMBMEM (Chapter 3) works, so SysVars also contains a pointer to a valid MCB chain. Of course, this MCB chain represents only the megabyte of VDM memory, not the entire OS/2 address space.
- DEVICE (Chapter 7) works, so SysVars contains a valid NUL device header pointing to a valid device header chain. This is only the DOS device driver chain for the VDM, including device headers loaded by VDHINSTL.SYS (see below). OS/2 physical device drivers (PDDs) are a separate, but coexistent, collection in DOS protected mode (see "A Roadside Walking by OS/2 Device Drivers," *Dr. Dobb's Journal*, August 1990). They use a separate VDD chain.
- DEVS (Chapter 8) fails with an error message that the NUL is absent in the VDM. Note however that OS/2 sets the first NUL link pointer to 0FFFFh. All structures which are used by OS/2 applications (see Duncan and Hogan, *ibid.*) are present and correct.
- INSTALL (Chapter 8) reports correctly that OS/2 does have a CDS structure, and it correctly displays the pointer to the Per-Task Data Area (PTDA; see Duncan and Hogan, p. 236).
- PTDA.COM (Chapter 8) tells us correctly that the network redirector interface isn't supported.
- INRs (Chapter 9) work, including those that use the SDA.
- Other programs that work include: RENAME (INT 21h AH=56h), BOOTOS (PSP:parent check), INSTCMD (INT 2Fh AH=ADh installable commands), ENVEDIT (master environment), and INTRSPY (intercepting interrupts).

However, most DOS device drivers, OS/2 treats as physical DOS device drivers. If a DEVICE= statement appears in CONFIG.SYS for what is determined to be a DOS device driver, then the DEVICE= or DEVICEHIGH= is passed on to become DOS DEVICE= setting. These settings apply to VDMs. Thus, a VDM would load a DOS device driver in each VDM. Only character DOS drivers are supported. For example, to load ANSI.SYS into a VDM you have a choice. Either place

DEVICE=C:\OS2\MDOS\VNSI.SYS in CONFIG.SYS so it will be loaded into all VDMs or add C:\OS2\MDOS\VNSI.SYS to the DOS DEVICE setting for the particular VDMs to which you want it loaded.

OS/2 provides a VDHSetDosDevice() function which links a DOS device driver header into the chain of drivers to be passed to a DOS session or VDM creation. For example, the VANSI.SYS VDD uses this function to "leave a fake ANSI$ device driver in the VDM's address space." This is similar to the DOSMGR Add_Device function in Windows Enhanced mode, which we discussed in Chapter 1.

We asked each of the MVDM developers at IBM to summarize what DOS programmers can do to help their programs run in DOS emulation environments such as OS/2.

> In the seven years I've worked at DOS emulation, I've seen an unbelievably narrow set of bad programs. I've come up with a real quick, simple test of what makes a DOS program well behaved. On a DOS machine, run the program. Then load SHARE and run it again. You can't believe how many programs fail even on a generic DOS machine with SHARE loaded. The single biggest offender is INT 21h, AX=3300h, upon compatibility mode. Compatibility mode wasn't a biggest mistake DOS 3.0's all have possibly made. If I had to give DOS programmers suggestions on programming, number one on my list would be never, never, never use 3300h. Why? Compatibility mode changes mean programs under different circumstances. A compatibility mode open on one LAN will not behave the same on a different LAN, or on no LAN.
>
> Other suggestions:
>
> Check return codes from the carry flag. You can't believe how many programs never do this!
>
> Avoid using the volume label in conjunction with other bits in the Find First/Next calls. DOS introduced some hasty bugs here.
>
> Don't expect handle things to always work. For example, opening a file and, while it is open, trying to delete it. Or opening a file with read/write access on a read-only media such as CD-ROM.

New OS/2 Services for Old DOS Programs

Now that we have some idea of how to support OS/2 provides for the standard DOS interface, what sort of new functionality does OS/2 provide to DOS programs?

The OS/2 API services are not directly available to DOS programs running under OS/2, just as Windows API services are not available to DOS programs running under Windows. However, OS/2 does let DOS programs access a number of extensions to INT 21h, to provide selected portions of the OS/2 API access call to DOS programs running in a VDM. I use these INT 21h extensions in a DOS program running under OS/2 to call access some of the drivers' services, to provide functionality described in IBM's *OS/2 2.0 Control Program Programming Guide*.

First, there is the set of functions OS/2 1.x added as part of the Family API (FAPI) meant to support Extended Attributes (EAs):

```
INT 21h AX=5702h     DosQueryPathInfo() (1 1+) and DosQueryFileInfo() (1 2+)
INT 21h AX=5703h     DosSetPathInfo() (1 1+) and DosSetFileInfo() (1,2+)
INT 21h AX=6C01h     DosOpen2()
INT 21h AH=6Dh       DosMkDir2()
INT 21h AH=6Eh       DosEnumAttrib()
INT 21h AH=6Fh       DosQMaxEASize()
```

The INT 21h AX=5702h and AX=5703h Extended Attribute functions are the most important. These allow a DOS program to indirectly call the OS/2 DosSet/QueryPathInfo/FileInfo() functions, which are described in detail in IBM's documentation. Interestingly, IBM's DOS 4.0 also supported these INT 21h Extended Attribute calls. To use the INT 21h calls, set the Info_Level_Return_Disk

any additional information can be inferred from Chapter 5 on Extended Attributes in IBM's *Control Program Programming Guide*. As a side note, it's worth pointing out that any programs that hook the normal MS DOS INT 21h AH=57h (Get/Set File Date and Time) functions will need to explicitly ignore these OS/2 Extended Attribute functions.

JOIN and SUBST are provided in DOS boxes under OS/2, but they are implemented quite differently than JOIN and SUBST in real mode DOS where they muck around with DOS internals. Since JOIN and SUBST are built into the OS/2 file system as kernel services, the JOIN and SUBST commands for OS/2 DOS boxes need to call into the kernel using INT 21h AH=61h:

```
; OS/2 INT 21h AH=61h JOIN/SUBST function
AH = 61h
AL = 0 (List), 1 (Add), 2 (Delete)
BX   drive number
CX = size of buffer
SI = 2 (JOIN), 3 (SUBST)
ES:DI -> buffer
BP = 'dg' magic signature
```

DOS programs running under OS/2 can access *named pipes* using the normal DOS open/read/write/close INT 21h AH=3Dh/3Eh/3Fh/40h calls on files such as \PIPE\PipeName or \\SERVER\PIPE\PipeName. For named pipe support beyond the basics there is a standard (though undocumented) LAN Manager/Server named pipes interface:

```
INT 21h AX=5F32h      DosQNmPipeInfo
INT 21h AX=5F33h      DosQNmPHandState
INT 21h AX=5F34h      DosSetNmPHandState
INT 21h AX=5F35h      DosPeekNmPipe
INT 21h AX=5F36h      DosTransactNmPipe
INT 21h AX=5F37h      DosCallNmPipe
INT 21h AX=5F38h      DosWaitNmPipe
INT 21h AX=5F39h      DosRawReadNmPipe
INT 21h AX=5F3Ah      DosRawWriteNmPipe
```

OS/2 2.0 itself uses these named pipe functions to implement DOS clipboard transfer and DOS dynamic data exchange (DDE). OS/2 2.1 instead uses the VWIN.SYS VDD which improves performance. For more information on these functions see Alex Shields article, "The Undocumented LAN Manager and Named Pipe APIs for DOS and Windows," *Dr. Dobb's Journal*, April 1993.

OS/2 2.x makes major extensions to DOS using INT 21h AH=64h. The handler for INT 21h AH=64h first looks at the CX register. If CX=6386h (the developer's initials), then it's an OS/2 request. If not, then the handler jumps to the code for DOS extended open (INT 21h AH=6Ch). This is a hack around a bug in API that passed INT 21h AH=64h rather than AH=6Ch for the DosOpen2() function.

If OS/2 INT 21h AH=64h handler finds the CX magic signature, it examines the BX register. If BX=0, it's a special request (see below). Otherwise, BX is the DOSCALLS ordinal number of an OS/2 API DosXXX function to execute.

OS/2 API functions (as Windows API functions) are exported from dynamic link libraries (.DLLs) and DLL exports have an "ordinal number" given as decimal. For example, the OS/2 Dos32StartSession API function is DOSCALLS 37. DOSCALLS is the module name for the OS/2 kernel (many of these kernel services are actually provided by OS2KRNL rather than by DOSCALLS.DLL, but that's another story). DOSCALLS ordinal numbers: INT 21h AH=64h expects a DOSCALLS ordinal number in BX. 0 is not a valid ordinal number, which is why this indicates a special request. However, not all OS/2 DOSCALLS functions are callable from a DOS program via INT 21h AH=64h, this interface supports only a specific subset of OS/2 APIs.

```
INT 21h AH=64h BX=DOSCALLS ordinal (decimal) CX=636Ch
BX=37 (25h)     Dos32StartSession (see below)
```

```
BX=130 (82h)    Dos32GetCP
BX=167 (A7h)    Dos32QFSAttach
BX=191 (BFh)    Dos32EditName
BX=203 (CBh)    Dos32ForceDelete
BX=324 (144h)   Dos32CreareEventSem
BX=325 (145h)   Dos32OpenEventSem
BX=326 (146h)   Dos32CloseEventSem
BX=327 (147h)   Dos32ResetEventSem
BX=328 (148h)   Dos32PostEventSem
BX=329 (149h)   Dos32WaitEventSem
BX=330 (14Ah)   Dos32QueryEventSem
BX=331 (14Bh)   Dos32CreateMutexSem
BX=332 (14Ch)   Dos32OpenMutexSem
BX=333 (14Dh)   Dos32CloseMutexSem
BX=334 (14Eh)   Dos32RequestMutexSem
BX=335 (14Fh)   Dos32ReleaseMutexSem
BX=336 (150h)   Dos32QueryMutexSem (*)
BX=337 (151h)   Dos32CreateMuxWaitSem (*)
BX=338 (152h)   Dos32OpenMuxWaitSem
BX=339 (153h)   Dos32CloseMuxWaitSem
BX=340 (154h)   Dos32WaitMuxWaitSem
BX=341 (155h)   Dos32AddMuxWaitSem
BX=342 (156h)   Dos32DeleteMuxWaitSem (*)
BX=343 (157h)   Dos32QueryMuxWaitSem (*)
```

The most useful of these functions is DosStartSession(), which a DOS program can use to start up other programs, including even OS/2 programs. The ability to launch OS/2 programs is not available with the DOS EXEC (INT 21h AH=4Bh) function, which will simply run the MZ portion of any file passed to it, so the following is quite useful:

```
DosStartSession
Entry
    AH = 64h
    BX = 37 (25h)
    CX = 636Ch ('cl' signature)
    DS:SI = STARTDATA structure
Exit
    AX = return code
```

The STARTDATA structure is the same one used by OS/2 programs that call DosStartSession(), and includes the program name, the command line arguments, environment, session type, initial screen size, initial screen position, title, and so on. For the format of the STARTDATA structure, see Chapter 7, "Program Execution Control," of IBM's *OS/2 2.0 Control Program Programming Guide*.

In OS/2 2.1, LINK386 uses INT 21h AH=64h DosStartSession call to implement a secret, new, undocumented switch: RUNFROMVDM. Normally, the OS/2 linker binds an OS/2 application with a DOS stub that just prints a "This program requires OS/2" error message and exits. RUNFROMVDM.EXE uses a stub that uses this INT 21h AH=64h DosStartSession call. Windows badly needs something like this. Microsoft's WINSRVR.EXE and WINAPP present one solution to this problem, but really, this function also needs to be built into Windows itself.

Returning to the other INT 21h AH=64h functions: If CX=636Ch but BX is not a valid DOSCALLS ordinal number, then the DX register indicates a special function. The Interrupt List on the accompanying CD describes these calls in more detail:

```
INT 21h AH=64h BX=0 CX=636Ch DX=subfunction
DX=0    Enable Automatic Title Bar Switch
DX=1    Set Session Title Bar
DX=2    Get Session Title Bar
DX=3    Get LASTDRIVE (used by WIN-OS/2)
DX=4    Get Size of PTDA JFT (used by WIN-OS/2)
```

```
DX=5    Get OS/2 SET Second Flags Word (print spooling?)
DX=6    Unload DOSRRNL Symbols and Load Program  (debugging)
DX=7    Get MIN-OS/2 Call Gate Address
DX=8    Get Loading Message (used by NLS)
```

As a final example of functionality that OS/2 provides to DOS programs, the OS/2 2.x VIDEO SWITCH NOTIFICATION setting enables and disables the INT 21h AH=40h screen switch API. On OS/2 1.x, by default, OS/2 doesn't issue the INT 21h AH=40h calls VIDEO SWITCH NOTIFICATION itself, because issuing them has some implications for Super VGA and XGA displays. Windows also supports these screen switch functions, which are documented in the Windows DDK; see INTRUPT.INF on disk for further details.

This completes our whirlwind tour of the additional interrupt-based APIs that OS/2 provides to DOS programs. Remember, however, that any VDD can provide this sort of functionality to DOS programs, not just OS/2's VDM. We've just looked at what happens to come built in to OS/2, but the situation with Windows Enhanced mode, where the additional functionality that VxDs can provide to DOS programs is potentially infinite, even if it is correctly layered. Some of you may have to write a VxD or Windows or a VDD in OS/2 to make new APIs available. Others may also have to consider whether the benefits of the additional functionality are worth the additional overhead of the virtual device driver; remember DOSSHELL in Chapter 3?

DOS Emulation Under Windows NT

Windows NT is Microsoft's latest attempt to build a "real man's" operating system with genuine threaded-based preemptive multitasking, demand-paged virtual memory, built-in networking, an improved security scheme, improved OLE, portability, and symmetric multiprocessing. Windows NT runs not only on Intel 80386 and higher processors but also on RISC processors such as the MIPS R4000. NT likes generous helpings of memory; it runs reasonably on 12 or 16 megabytes of memory.

For the foreseeable future, NT will be a niche product. According to *Barron's* (April 5, 1993), Rich Barth, a product manager for Windows NT at Microsoft, "says that out that over the next two years 80% of the people using PCs won't need the kind of computing power NT provides." Microsoft intends NT to be a replacement for MS-DOS or Windows, but as a way to perhaps conquer new-to-PC markets, recently joined by companies such as IBM and Novell. Even Microsoft's executive VP, Steve Ballmer, "acknowledges that when NT is introduced, it will at first be little more than a niche business." (*New York Times*, May 26, 1992). Mike Maples, another Microsoft executive VP, more recently reiterated the company's not-so-great expectations for NT by stating, "If you don't know a reason you need NT, then you don't need it." ("Microsoft Soft-Pedaling Its Latest," *New York Times*, May 24, 1993). In the next few years, perhaps fewer than 20% of existing Windows 3.1 users will move over to Windows NT.

If programmers are considering whether to "bet the farm" on NT, this point is really important. Microsoft has several times expressed about how NT will play a relatively small role in the PC market place. Of course, it also wants to replace Windows 3.1 and how it is intended especially for network server machines. Developers would be well-advised to pay careful attention to what Microsoft is actually saying about NT and not simply pick up on the *amount* they're talking about it. Frankly, Windows NT could turn out to be another OS/2 Yawn.

It is important to distinguish NT from the Win32 API. Microsoft's intended successor to the 16-bit Windows API. Whatever happens with NT, Win32 seems like a clear winner. Win32 is not at all tied to NT. A subset runs today on Windows 3.1 Enhanced mode. Win32s and a larger subset will run on Chicago (DOS 7.0 and Windows 4.0) scheduled for release in 1994. In contrast to the prodigious memory requirements of NT, Microsoft's slogan for Chicago is "runs great in four megabytes."

Generally, when developers say they are writing an NT application, they really mean they are writing a Win32 application.

Just as Win32 applications don't run only on NT, conversely, NT does not only run Win32 applications. Think of NT as a motherboard into which you can plug multiple daughterboards. In NT terminology, these are "subsystems." Win32 is one such NT subsystem; others are WOW (Win16 on Win32) responsible for running 16-bit Windows programs on NT, an OS/2 1.x subsystem, a POSIX subsystem, and a second, MS-DOS subsystem called NTVDM.

As in OS/2 2.x, the term VDM means Virtual DOS Machine. Like OS/2 and Windows Enhanced mode, NT runs real-mode DOS programs in Intel's 8086 mode at the CPU's lowest privilege level, Ring 3. As you'll see, there are a number of similarities between the NTVDM subsystem and the MVDM part of OS/2 2.x. This is hardly surprising because before Microsoft's breakaway from IBM and its development of OS/2, Microsoft worked on OS/2 MVDM. The NTVDM team at Microsoft is led by Matthew Felton, who, according to Helen Custer's *Inside Windows NT*, had previously worked on OS/2's DOS compatibility environment. Matt has been kind enough to provide much of the following material. Other material in this section comes from a talk by Sanjeep Bhatia on "Virtual Device Driver Support on Windows NT," Microsoft's NT device driver developer's conference, October 1992. Yes, like OS/2 2.x and Windows Enhanced mode, NT also has virtual device drivers, as OS/2 does, are called VDDs rather than VxDs. However, unlike Windows VxDs and OS/2 VDDs, NT VDDs run in Ring 3 user mode, rather than in Ring 0 kernel mode. NT has separate kernel-mode device drivers that run in Ring 0.

The Client/Server Model

As with MVDM in OS/2, the goal of NTVDM is to run DOS applications without DOS. Old DOS programs continue to make DOS INT 21h calls, but these are sometimes serviced using Win32 calls. In the remainder of this chapter, we'll try to make this "sometimes" part more concrete.

As an example, consider a simple program written in C that uses standard C runtime library functions such as open, read, write, and close. If this program is built with a C compiler for DOS, the resulting executable contains DOS calls such as INT 21h AH=3Dh or AH=6Ch to open the file. Most C runtime libraries and MS-DOS executables. The program uses the DOS "MZ" executable format. When you build the same program for NT, this program can be recompiled for Win32 without changing a single line of source code. The resulting executable is a Win32 PE executable that contains Win32 API calls (for example, instead of using INT 21h AH=3Dh or AH=6Ch to open a file, the recompiled Win32 version will contain a call to the Win32 CreateFile function). Win32 existing files are opened with CreateFile. The ability to target multiple operating systems from a single source code is called *source compatibility*. It's not always difficult to achieve.

While source code is the programmer's source of power, it is also the source of much grief for users. To satisfy the large and vocal group of people who use operating systems, NT must support *binary compatibility* with existing executables, for popular operating systems. NT must be able to take old DOS executables, convert INT 21h calls and structures, INT 21h calls as soon as it sees that the application is about to execute ReadFile. Write file, and so on. To a certain level, that a call to INT 21h AH=3Dh turns into a call to CreateFile.

There's not merely some minor structural differences between INT 21h AH=3Dh and CreateFile. Not only is DOS really a 16-bit DOS program running under NT, even on a 32-bit 80x86 machine. NT supports DOS emulation on RISC machines too. Even on 32-bit machines, the hard disk may have been formatted using the old DOS file allocation table (FAT) format. NT also supports OS/2's high performance file system, HPFS, and a new NT file system, NTFS. How can an old DOS program be made to work with all this new-fangled non-DOS non-FAT possibly non-Intel stuff?

Actually, this isn't all that different from something that already takes place today under DOS. The DOS network redirector allows DOS INT 21h file I/O and directory calls to be serviced using files and directories located on other machines. As explained in Chapter 8, these other machines are probably not even running DOS. All a DOS program knows is that it issues the right INT 21h AH = 3Dh invocation to open a file and—ow and behold—it gets back a file handle. Most programs hardly care where the file handle came from. If the handle represents a file located on a NetWare file server, a MIPS R4000, a SunSparcStation, or a Macintosh, that makes no difference.

This network redirection sounds the same as what must go on when you run a DOS application under a true DOS operating system such as NT. And except for the fact that the DOS client and the Win32 server may be located on a single machine and not the same, NT is built around the client/server model. Rather than have the operating system provide APIs directly, all APIs are instead provided by subsystem servers which have just more or less normal user-mode applications.

Supporting DOS INT 21h requests with the ideas which NT borrows from the Mach operating system—that APIs and other facilities normally regarded as part of the operating system can instead be provided by user-mode applications. In other words, NT services a DOS application's INT 21h requests in the same way that it services a Win32 application's Win32 calls: with a subsystem. For a detailed explanation of the NT client-server architecture, see Helen Custer's book *Inside Windows NT*, particularly the chapter on protected subsystems. For client-server operating systems in general and a thorough look at Mach, see Andrew Tanenbaum's brilliant *Modern Operating Systems*.

NTVDM, NTIO, and NTDOS

Now that we've established how NT runs DOS applications without DOS—possible without the FAT file system and possibly without an Intel processor—let's look at what happens when a user starts a DOS program under NT.

When NT runs programs with the Win32 CreateProcess() API. When a user clicks on a program's icon in the NT Program Manager, CreateProcess() is called even if the program is a DOS program or a 16-bit Windows application.

CreateProcess() is perhaps one of the most low-level undocumented functions that it provides. See "Undocumented NT" later in this chapter. CreateProcess() inspects each EXE file to see the type of program it has been asked to create. All EXE files have two-byte signatures (magic numbers) indicating their type. Win32 executables use Microsoft's Portable Executable file format and have a "PE" signature. Both Win16 and OS/2 2.x executables use the New Executable file format and have "NE" signatures; there is an additional target operating system tag in the executable header that distinguishes Windows and OS/2 1.x programs. Both the NE and PE formats are supersets of the old DOS executable format, which starts with an "MZ" signature (the initials of Microsoft's Mark Zbikowski). Thus if CreateProcess() is handed a file with only an "MZ" signature, CreateProcess() knows it is dealing with a DOS program. The same is true for .COM files, which have no header at all. An NE header with Windows as the target is a Win16 executable.

CreateProcess() deals with both DOS and Win16 executables by looking up a command line in the NT registry's default.com command line tells CreateProcess() to instead run a Win32 executable, NTVDM.EXE, and pass it the name of the original DOS or Win16 program in which the user is actually interested. In other words, clicking on the DOS program FOO.EXE results in the execution of the command "NTVDM FOO.EXE".

NTVDM.EXE is not a DOS program but a user-level Win32 application. It creates a VDM in which a DOS program or Win16 program can run in V86 mode. In this VDM, it loads and starts NTIO.SYS—a real-mode DOS-like executable (0070:0000). NTIO.SYS loads another file, NTDOS.SYS, and then processes CONFIG.SYS. If CONFIG.SYS contains HIMEM.SYS and a DOS=HIGH statement, some of the code is moved to the portion of the VDM that lies just above one megabyte.

The names NTIO.SYS and NTDOS.SYS should sound familiar. These are hacked versions of IO.SYS and DOS.SYS, which form the core of MS-DOS 5.0 (see Chapter 6). While modified for NT, they are still real-mode DOS programs. These files represent the 16-bit side of the NT DOS emulation layer. There is also a hacked copy of COMMAND.COM, which processes AUTOEXEC.BAT (the program that the user asked to run is loaded in this environment).

Magic Pills and Bops

How do the NT files NTIO.SYS and NTDOS.SYS differ from the DOS files IO.SYS and MSDOS.SYS? For one thing, Microsoft has removed all hard-wired assumptions about the FAT file system. As an example of the changes made to IO.SYS and MSDOS.SYS to create NTIO.SYS and NTDOS.SYS, consider the following code fragment from MSDOS.SYS in DOS 5.0:

```
mov ds, cs:DOS_DS
lds si, dword ptr ds:PTR_CURRCDS
test word ptr [si CDS_ATTRIB], NET_REDIR     , test [si+43h], 8000h
```

The equivalent code in NTDOS.SYS looks like this:

```
mov ds, cs:DOS_DS
lds si, dword ptr ds:PTR_CURRCDS
db 0C4h, 0C4h, 58h, 13h
```

On Intel processors, C4h C4h is an illegal instruction that decodes as LES AX,SP. Executing this illegal code in V86 mode causes a trap into whatever protected mode software is acting as the V86 monitor. In NT, this monitor is NTVDM.EXE.

Remember that DOS 2.2 was the version of the IBM compatibles ported earlier in this chapter described as DOS 2.x single-port or XPRT, which stood for the same purpose. Windows 3.0 needed real mode? Those words sometimes are not the only ones that matter. Real mode to protected mode. This is necessary because we are forced to write real-mode code to run on a machine with 32-bit protected mode. Well, call it C4 C4 mode in NTDOS.SYS, for short.

C4h C4h is also used to call the NTVDM.EXE file in the NT device driver KE.DDK. BOP stands for BIOS operation, which is Microsoft's term for whatever purpose it uses this mechanism. It allows 16-bit real-mode code, such as DOS device drivers, to call down to 32-bit protected-mode code, such as NTVDM and NTVDDs.

NTVBOP.EXE defines these macros supporting third-party bops:

```
RegisterModule      db C4h, C4h, 58h, 0
UnRegisterModule    db C4h, C4h, 58h, 1
DispatchCall        db C4h, C4h, 58h, 2
```

Any DOS software running under NT can use these services, which are documented in the NT DDK *Win32 User-mode DDKs: Base Services* and *Win32 User-mode DDKs: Win32 Device Guide*. Because NTVDM is running with a 32-bit protected-mode flat address space, its 16-bit DLLs are nothing more than DLLs and thus can call the Win32 API functions such as CreateFile, ReadFile, and so on. RegisterModule exposes the NTVDM code that loads a DLL and finds its Dispatch() entry in the DLL. It returns a handle which a 16-bit DOS program can then pass to DispatchCall to call entry points in the 32-bit DLL. Clearly, this is how 16-bit DOS programs indirectly call Win32 functions.

Looking back at the code fragment from NTDOS.SYS, you can see that the string C4h C4h 58h is the code used for calling all of the other services from NTVBOP. As noted earlier, NTVBOP supports third-party bops. Microsoft uses its own bops that NTIO.SYS, NTDOS.SYS, and COMMAND.COM use:

```
BOP_DOS             C4h, C4h, 50h       Used in NTIO.SYS, NTDOS.SYS
BOP_WOW             C4h, C4h, 51h       Win16 on Win32
BOP_XMS             C4h, C4h, 52h
```

```
BOP_DPMI                C4h, C4h, 53h
BOP_CMD                 C4h, C4h, 54h       COMMAND.COM to CMD.EXE?
BOP_DEBUGGER            C4h, C4h, 56h
BOP_REDIR               C4h, C4h, 57h       Used to be 55h
BOP_3RDPARTY            C4h, C4h, 58h       See I$VBOP.H  RegisterModule, etc
BOP_NOSUPPORT           C4h, C4h, 59h       Host warning dialog box
BOP_GRABTIMER           C4h, C4h, 5Bh       Check whether timer INTs required
BOP_KBD                 C4h, C4h, 5Ch       temporary?
BOP_VIDEO               C4h, C4h, 5Dh       temporary?
BOP_NOTIFICATION        C4h, C4h, 5Eh       16-bit to 32-bit notification
BOP_UNIMPINT            C4h, C4h, 5Fh
BOP_SWITCHTOREALMODE C4h, C4h, FDh
BOP_UNSIMULATE          C4h, C4h, FEh       End execution of code in a VDM
```

Except for a few instructions, Microsoft has thus defined its own little pseudo like bop instructions. NTIOSYS.SYS or NTIODOS.SYS use these bops, especially BOP_IODOS essentially as SVC (supervisor calls).

Bops Through History

Microsoft's use of illegal instructions to make the hyperspace jump from 16-bit real mode to 32-bit protected mode sounds like an *ad hoc* hack that someone came up with in two minutes. It's not. In fact, this bop technique of using an illegal instruction as a supervisor call dates back over twenty years to IBM's VM/360 operating system, where a nonexistent instruction, often referred to as DIAGNOSE, was used to force an exception with a virtual machine, so that the exception could be caught by the VM kernel and interpreted as a service request.

For more information on the history of this great hack, see the letters to the editor in *Windows DOS Developer's Journal* (July 1993 (pp. 99-100). These letters were prompted by a correction to earlier articles on NT VDDs (Paula Tomlinson, "Windows NT Virtual Device Drivers for Hardware-Dependent 16-Bit Applications," *Windows DOS Developer's Journal*, May 1993), which included a short sidebar on bops ("The VDD Backdoor").

Most 16-bit real-mode DOS software from third-party vendors uses bops to communicate with VDDs that extend the NTVDM box (see the chapter on "Virtual Device Drivers for MS-DOS Applications That Use Special Hardware"). It also shows how to use the RegisterModule and Dispatch bops from within a VDD that supports something like a FAX board or a 3270 communications board.

But bops are really much more general purpose than that. Any DOS program could use bops to address the VDD services that I called Ring-3 APIs on the DOS program's behalf. If the bop is placed in DOSKRNL, as for example DSR (the normal DOS programs that call the device driver or TSR will not even notice the bop we took out of being aware of it. This transparency, of course, is the whole idea behind RPC. Bops are thus a quick-and-dirty way to provide the transport layer for a form of remote procedure call (RPC).

What is NTVDM.EXE?

Most of the bop handlers are located in NTVDM.EXE, which, when we last left it, had started a VDM and loaded NTIOSYS and NTIODOS.SYS. When these hacked versions of DOS 5.0 issue a bop such as C4h C4h 53h, the NTIODOS.SYS code fragment above will be handled in NTVDM.EXE.

NTVDM.EXE is a PE executable and can be examined with a utility such as Microsoft's COFF.EXE (COFF stands for Common Object File Format, a UNIX standard upon which PE is based).

COFF EXE can execute under DOS using Phar Lap Software's TNT a 32 bit DOS extender that runs NT executables under MS DOS For example

```
tnt \mstools\bin\coff dump -exports -imports \nt\i386\ntvdm exe
```

Actually, as this book was going to press Microsoft replaced COFF EXE with LINK32 exe Examination of NTVDM EXE with COFF shows that NTVDM exports a number of functions for use by VDDs, such as VDDInstallIOHook VDDInstallMemoryHook and so on (See the NT DDK documents these functions) NTVDM also imports functions from KERNEL32 DLL USER32 dll and GDI32 dll These dynamic link libraries contain the functions documented in the Win32 SDK Naturally since Microsoft controls software after all NTVDM EXE also imports a number of undocumented functions from KERNEL32 such as InitVDM GetNextVDMCommand RegisterConsoleVDM and VDMConsoleOperation and uses an NtVdmControl function from NTDLL DLL You will see later that NTDLL DLL is a gateway to the undocumented "native" NT API

NTVDM EXE contains a number of components

DEM32 is the 32 bit code that processes the left side of DOS emulation DEM When NTIO SYS or NTDOS SYS issue a hop, it comes to DEM32

NTVDM also contains a *built in 16 bit emulator* (VDM) which handles all the DOS program instructions such as IN OUT and INT that are illegal under DOS emulation For example INT 21h is an illegal instruction in Ring 3 Illegal exceptions occur when the CPU encounters an illegal instruction or when Ring 3 code tries to execute a privileged instruction such as IN or OUT Illegal exceptions cause a trap into NTVDM which examines the trap frame to determine the cause of the trap If the trap was caused by an illegal instruction NTVDM passes the trap frame to the DOS emulator

On non Intel machines (the DEC Alpha and MIPS machines) NTVDM contains an Intel 80486 emulator which supports executing up to 80286 protected mode instructions (Insignia Solutions has a SoftPC AT Executive for the Alpha) There are different versions of NTVDM EXE for different processors For example in addition to the Intel version (i386\NTVDM EXE) there is also one for the R4000 MIPS (mips\NTVDM EXE) However the exact same NTIO SYS and NTDOS SYS files are used on Intel machines as are used on MIPS machines

As noted earlier NTVDM exports functions for use by VDDs These are documented in the NT DDK (*Win32 Device Driver Kit: Kernel Mode Drivers*, see the chapter "Virtual Device Drivers for MS DOS Applications" and the "Special Topics" section) (*Inside Windows NT*, *Inside Device Drivers*)

NTVDM not only exports functions to VDDs it also contains the VDDs for serial and PC style parallel ports video timer interrupt controller and so on These VDDs allow DOS applications running under NT to talk (that is generate I O ports relating to memory locations or hardware interrupts) to virtual devices Although they will usually be executing on a PC or similar processor the device is virtual, not real The VDD using NTVDM functions such as VDDInstallIOHook and VDDInstallMemoryHook sets up to trap the known low level interfaces to pieces of hardware The actual hardware may or may not exist To maintain the illusion of total control the DOS applications must not be allowed to "poke" the Microsoft hope will (in actual networks) exist for files exist An exception is a DOS application running full screen (not in a window) which is allowed to directly hook video interrupts

All this sounds a lot like OS 2 and Windows Enhanced mode It's similar except that these systems are limited practically speaking to Intel machines This is not much of a limitation since the RISC machines (i e NT) tend to already have such a small market share as to be a moot point

In addition NTVDM runs all of its code in user mode Ring 3 Win32 DLLs and even critical Ring 0 parts of the kernel (see Windows Vxds and OS 2 VDDs) Because they are not in user mode Win32 DLLs VDDs like NTVDM EXE cannot use Win32 API another difference from Windows Vxds which cannot make direct Windows API calls

So how do all these pieces thus fit together?

NTVDM.EXE creates a VDM, starts NTIO.SYS and NTDOS.SYS in the VDM, and starts the DOS application that the user wants to run. The DOS application makes INT 21h calls, which go to NTDOS.SYS, which hops down to NTVDM. NTVDM contains VDDs; additional VDDs can handle any other hardware that NTVDM doesn't support. NTVDM and VDDs are Win32 DLLs, so they can make Win32 API calls on the DOS program's behalf.

To implement INT 21h calls, NTVDM calls functions in KERNEL32.DLL. KERNEL32 contains not only the 32-bit equivalents of Windows API functions from KRNL386.EXE, but also a set of new Win32 API functions intended to replace the DOS functions that Win16 applications use. KERNEL32.DLL contains functions such as CreateFile, ReadFile, WriteFile, CloseFile, CopyFile, MoveFile, CreateDirectory, SetCurrentDirectory, RemoveDirectory, DeviceIoControl, FCLOSE, and so on. Note that most of these functions are the 32-bit versions of the functions exported from KERNEL32.DLL. For example, CreateFile actually is CreateFileA (ASCII filenames) and CreateFileW (Wide = Unicode filenames). NTVDM uses KERNEL32 to carry out DOS program's file I/O and directory requests.

KERNEL32.DLL also contains a set of Console functions to support character mode Win32 programs. (Of course, Windows doesn't have something like Console.) NTVDM uses the KERNEL32 Console functions to carry out a DOS program's standard input and standard output I/O.

Remember that when a DOS program running under NTVDM.EXE calls INT 21h AH=3Dh or AH=6Ch to open a file, NTVDM somehow has to turn around and make a call to CreateFile. The "somehow" part should now be clear: NTVDM hops down to NTDOS which hops down to NTVDM.EXE, which then calls CreateFile on the DOS program's behalf.

But what happens when CreateFile returns a 32-bit file handle? This cannot be returned to a real DOS program, which expects a 16-bit file number in AX. Instead the 32-bit Win32 file handle is stored in the NTDOS SFT, which Microsoft has modified from the DOS original. Just as before, DOS uses SFT entries to store information about files opened by DOS programs. If a file is associated with an "NT" file, the SFT entry contains the Win32 file handle. In other words:

```
MS-DOS:  File handle => JFT => SFT
NTDOS    File handle => JFT => modified SFT => Win32 file handle => ?
```

Just as NTDOS must keep track of file handles used in the DOS 2.2 x/VDM/DOS 2.0x "" case, it happens that NTDOS must keep track of SFTs. The DOS 2.11 SFT and NTDOS SFT are quite similar, but something similar happens as NTDOS tries to preserve the DOS 3.x SFT. NTDOS uses its DOS file I/O requests and returns the DOS SFT entry that it has created. Then, it applies a mask to the structure to create the NTDOS SFT. (DOS 4 models it after that.) NTDOS is hopping down to NTVDM, which in turn is calling CreateFile in KERNEL32 and so on.

DOS 5.50

Chapters 15 to 17 are primarily devoted to other parts of this book. We care about the structure of SFTs and other undocumented DOS structures. So we will better take a few minutes to see what support NTDOS has for undocumented DOS programs.

When you run NTVDM /D, the application will report that it is not running in a native MS-DOS environment. This is true of most DOS applications, but some will definitely fail. In this mode, NTDOS reports a DOS version of 5.50. We know that the 16-bit side of DOS emulation under NT was derived from a leaked version of MS-DOS 5.0, so the emulation is quite close. Even many of the differences between NT and DOS 5.0 are documented in the Resource Kit. Remember, also that this same DOS-based emulation is used on Intel and Alpha systems. NTFS as well as the FAT file system.

Even though NTDOS identifies itself as DOS 5.50, NTVDM advertises itself as DOS 20.0, so many NTDOS programs check for DOS 20.0 in the INT 21h AH=30h (Get Version) call. However, this caused many DOS programs that checked for DOS 3.0 or 4.0 to fail with error messages such as "This program can't run in a DOS 2 DOS box." The same programs were happy to run when NTDOS returned a 5.x ver

sion number so NTDOS now returns 5.0 from the INT 21h AH=30h. This at first sounds like a very bad move because it makes NTDOS difficult to distinguish from genuine MS-DOS 5.0. However under NTDOS the function to get the genuine DOS version (INT 21h AX=3306h) returns 5.0 32h as a major version. Thus NTDOS's version DOS 5.50 (emulation version of 5.0) is hard-wired into the NTDOS version of COMMAND.COM.

What undocumented DOS functionality does this DOS 5.50 support. Microsoft has said that NTDOS will support most undocumented DOS functions but will not support DOS programs that depend on internal structures. This appears to be accurate.

INT 21h AH=52h (which of course is supported) is some of the SysVars data structure. For example SysVars -21 points to the header block for MCB chain for the VDM. The COMMEM program from Chapter 7 works very much under NTDOS as does the WINDISP program from Chapter 3. Of course these programs see only the conventional/low memory part of the VDM.

Just as NTDOS provides an MCB chain, there is also a DOS device chain with the NUL device rooted at the proper location in SysVars. As a result the DEVICE program from Chapter 7 also runs much under NTDOS as does the WINDEV program from Chapter 3. According to Custer's *Inside Windows NT*, NT uses some of the DOS device names for NT device drivers.

In the INT 21h AH=63h example above we noted that NTDOS modifies the SET instruction for byte writes? Of course this in other words NTDOS can do SET but it is somewhat different from the one in MS-DOS. NTDOS in file operations are carried out using a combination of the Win32 side of the DOS emulation layer and the DOS SFT structure and needs to communicate to 16-bit DOS state. As a result the SFT entries used by NTDOS are 21h bytes instead of 3Bh bytes. NTDOS does maintain the SFT pointers in SysVars. Running SFT.WAK on running 3.5 indicates that NT automatically sets FILES=255.

The CDS in NTDOS is also basically different from the CDS in MS-DOS. NTDOS ignores the LASTDRIVE value in SysVars and that in MS-DOS LASTDRIVE holds the number of entries in the CDS array. Instead NTDOS creates one CDS for each physical drive and one for all the remote drives sweeping the single extended CDS in reserve. As a result the CDKV program from Chapter 2 which tests that the LASTDRIVE and SysVars the same as the LASTDRIVE returns a error. INT 21h AH=08h (open device) in NTDOS is weak. Normally the FINUM.DAT program from Chapter 8 usually fails with a "Bad get CDS" message because the value of LASTDRIVE is too low.

What about a proper CDS? Well surprisingly enough the DOS network redirectors work. Certainly the Phantom program from Chapter 5 does not work under NT (although perhaps Phantom is more dependent on the CDS than most redirectors). NTDOS comes with a VDMREDIR.DLL (and presumably alternate redirectors).

How about TSRs? Here the news is a bit better. All the TSRs from Chapter 9 work under NTDOS including those that hook the INT 2Fh AX=4300h and the Swappable Data Area. The only difference from MS-DOS is NTDOS's slightly more relaxed attitude to TSR misbehavior. When a TSR terminates using INT 21h AH=31h or INT 27h a message appears preceding the Windows NT memory resident support. This message indicates that you can press the TSR's hotkey or press Z to get back a command prompt. You are supposed to be able to hotkey into an TSR from a DOS program but this seems at best only to work on an occasional basis.

In fact TSRs don't seem to work very well inside DOS applications. What you need to get a command prompt. Next start your favorite DOS prompt but don't shoot. You're running CMD.EXE which is a Win32 console program. VDM remains attached to the Console window but in a most unusual fashion. When you run a DOS program the VDM window appears and does its thing. TSRs look to work only when a DOS program is actually running. CMD.EXE which provides the C> prompt is not a DOS program. If you want continuous access to a TSR then you should not press Z to return to the C> prompt. Instead get yourself a new Console window using the /c switch dedicated for the TSR.

Windows CMD.EXE is a Win32 program. It can run not only Win32 programs and, as you've seen, DOS programs but also Win16 character mode OS/2 and POSIX programs. Having one command prompt for everything is a welcome departure from the lame DOS command prompt in Windows. The hassle and slowness is livable without a lot of extra help to run Windows programs. Microsoft uses CMD.EXE in Server Command Next NOS. At the same time, NT still needs the real mode COMMAND.COM to process DOS batch files and generally to hang around in case DOS programs access it. For example, the undocumented COMMAND.COM backdoor INT 2Fh is available under NTDOS. Remember the INT21 program from Chapter 10 works very much.

Undocumented DOS calls are just one example of bad behavior from DOS programs that Windows NT/2000 has to support without compromising the integrity of the whole system. Another good example is the popular category of disk maintenance programs such as the Norton Utilities for PC. It is simply impossible for NTDOS to allow such programs to write to the hard disk. Even if you have a favorite DOS undelete or defrag utility, you'll have to boot generic MS-DOS to run it.

NT does not allow even a DOS program have direct *read* access to the hard disk. The ratio is that a DOS application would expect to find FAT disk structures, whereas in fact there might be an NTFS or HPFS. There may be ways in the future for NT to provide DOS programs with read access to hard disks, but write access is out of the question," says one of the NTDOS developers.

Other examples of restrictions or limitations on what even a native Win32 application can do to the hard disk. For instance, Norton Utilities for PC Tools could be ported to Win32, but the user would have to be logged on as administrator to open the hard disk. Direct disk access is initiated with a call to CreateFile, using a file name such as \\.\PhysicalDrive0. Furthermore, to write to the hard disk, the application would need to lock out other access to the device using FSCTL_LOCK_VOLUME. This only locks out the current drive, not any other open files on the drive. The paging swap file creates an open file that is very difficult to work with or repair. The disk where the swap file resides must be locked, and NT includes a tool called MS-DOS for a while that only exists to repair the massive hard disks NT needs.

Additional NTDOS Functionality

Having seen that NTDOS does not exist solely to provide support existing DOS functions, including the undocumented ones, let's look at some of the ways of supporting DOS internal data structures we need to write a new shell for DOS programs. The DOS programs do receive some positive benefits from running under NT. For example, DOS programs are generally much faster under NT than under genuine MS-DOS. Another reason is that you can run NTDOS just as a way to avoid having two machines on your desk or needing a DOS boot diskette.[3]

We could write a custom CMD.EXE that supports command shell and scripting in a similar manner to 4DOS. We won't bother to do so, but what seems very important is that CDM allows different types of processes to communicate. CMD.EXE allows *pipes* between all the different types of programs it runs. For example, a pipe between a DOS and a Win32 program is a single command line. An interesting article in the *Windows/DOS Developer's Journal* by John Richardson, "Escape from DOS," *WDJ*, April 1993, explains how Win32 programs can use these anonymous pipes to request services of Win32 programs.

Other than a Win16 application, which as we discussed in Chapter 3 is really just a fancy form of protected mode DOS application, and DPMI clients, can interact with Win32 applications using the clipboard and dynamic data exchange. Unfortunately, NT does not allow any further mixing. For example, Win32 programs cannot directly use Win16 DLLs and Win16 programs cannot directly call Win32 DLLs. The keyword "directly" is important here because numerous indirect methods, such as named shared memory and DDE, are available.

While the NT services for DOS programs look rather sparse, it's important to remember the third party hops that Microsoft supports. Using the RegisterModule and Dispatch call hops mentioned earlier, real mode DOS code running under NT can call down to a VDD which in turn can call an arbitrary Win32 API function on the DOS program's behalf. The NT DDK CD-ROM provides some good examples in the APPNTS.COM VDD, DOSIOCTL, and VDMINTS sample programs.

On the other hand, if software is prepared to modify their DOS program to use hops and is prepared to write a VDD to act as a Win32 surrogate for the DOS program, they should probably bite the bullet and port their program to Win32. The third party hops are probably best suited to a limited number of cases where the DOS software simply cannot be ported to Win32, but where there is an opportunity to either modify a small portion of it or to supply a DOS device driver or TSR that hops down to a VDD.

Undocumented NT

The goal of this chapter has been to discuss "other DOSs" avoiding major discussions of any other aspect of NetWare, OS/2, or NT. But in the case of Windows NT, it's difficult to resist a small peek at the broader topic of undocumented NT functions. Not only because many readers and Microsoft too, have asked us why *Undocumented NT* is coming out, but because the topic of undocumented NT hops is arguably the most critical of the NT operating system.

In connection with NT, Microsoft has produced massive amounts of programmer's documentation. This documentation states quite clearly that its subject is the Win32 API, that is, functions such as (to pick a few at random) CreateFileMapping, MoveWindow, and LoadIcon exported from KERNEL32.DLL, USER32.DLL, GDI32.DLL, and other Win32 dynamic link libraries.

This is *not* the NT API. I repeat, the point made earlier: Win32 and NT are not necessarily the same thing. Large subsets of the Win32 API run on platforms other than NT, for example, on Windows 3.1 (enhanced mode), Win32s, and Chicago. On NT, Win32 is just one subsystem. And NT supports APIs other than Win32, just as DOS was looked at as a potential example. Win32 was just privileged in that as we saw, it's used for the operation of other subsystems. It's also arguably part of the NT configuration, whereas the other subsystems are optional and can be kicked out. You can load an application that needs Win32, but no matter what, Win32 relates to NT in much the same way that DOS emulation does. It's a subsystem.

Because of NT's Win32 subsystem, any function call that is associated with the operating system kernel, such as API processing, have been removed into more or less normal applications which can be preempted, paged, located on other machines, and so on. It's not at all clear how many people really need this, but it's certainly cool.

So if Win32 and the other subsystems are all user level code, where is the operating system kernel? Didn't we see in KERNEL32.DLL what calls is coming in to get out of kernel mode but user mode code. We saw that the NtVDM subsystem is implemented in part using KERNEL32.DLL, but now KERNEL32.DLL itself implemented. And what was that NTDLL.DLL file that NTVDM.EXE also used?

Much of the general purpose NT API is exported from NTDLL.DLL. For example, Helen Custer's excellent *Inside Windows NT* mentions many NT objects such as Processes, Threads, Ports, Events, and so on, and refers to the types of operations these objects provide, such as Create, Open, Close, Query, and Wait. But understandably, the book doesn't discuss where to find these objects and operations.

If you examine NTDLL.DLL with a PE dumper utility, you will see that NTDLL exports many of the NT functions whose existence one would infer from *Inside Windows NT*. For example, here's a small portion of the NTDLL export table:

```
61      62    0000b810   NtConnectPort
62      63    0000b820   NtContinue
63      64    0000b830   NtCreateDirectoryObject
64      65    0000b840   NtCreateEvent
65      66    0000b850   NtCreateEventPair
66      67    0000b860   NtCreateFile
67      68    0000b870   NtCreateKey
68      69    0000b880   NtCreateMailslotFile
69      70    0000b890   NtCreateMutant
70      71    0000b8a0   NtCreateNamedPipeFile
71      72    0000b8b0   NtCreatePagingFile
72      73    0000b8c0   NtCreatePort
73      74    0000b8d0   NtCreateProcess
74      75    0000b8e0   NtCreateProfile
75      76    0000b8f0   NtCreateSection
76      77    0000b900   NtCreateSemaphore
77      78    0000b910   NtCreateSymbolicLinkObject
78      79    0000b920   NtCreateThread
79      80    0000b930   NtCreateTimer
80      81    0000b940   NtCreateToken
81      82    0000cd40   NtCurrentTeb
82      83    0000b950   NtDelayExecution
83      84    0000b960   NtDeleteKey
84      85    0000b970   NtDeleteValueKey
85      86    0000b980   NtDeviceIoControlFile
86      87    0000b990   NtDisplayString
87      88    0000b9a0   NtDuplicateObject
88      89    0000b9b0   NtDuplicateToken
```

You won't find any of these functions in the Win32 SDK or even in the NT DDK documentation some are mentioned in passing in DDK INC NTDDK.H and NTSTATUS.H. This really is undocumented. On the other hand, most of these functions do have documented equivalents in the Win32 API, so it's not clear how important undocumented NT really is to most programmers. For example, in early beta versions of NT, Microsoft's PVIEW (Process Viewer) utility relied heavily on functions in NTDLL.DLL. [illegible] March 1993 beta, much of the functionality upon which PVIEW relied had been incorporated [illegible] Win32 API.

So, even though NTDLL.DLL functions has equivalent functionality in Win32, which is not the case, it's probably not worth looking at this undocumented API. Helen Custer presents in her book.

So is NTDLL.DLL the genuine core of NT? Hardly. Looking back at the excerpt of the NTDLL export table, you may notice something odd. The third column shows the virtual address for each function. Most of the functions are only 16 bytes apart. Microsoft sometimes likes to brag about its "tight code," but it's unlikely that it has implemented each NT function in only 16 bytes. Disassembly of a small portion of NTDLL shows what's really going on. For example:

```
NtCreateProcess proc far
    mov eax, 1Ah
    lea edx, dword ptr [esp+4]
    int 2Eh
    retn 20h
NtCreateProcess endp

NtCreateProfile proc far
    mov eax, 1Bh
    lea edx, dword ptr [esp+4]
    int 2Eh
    retn 1Ch
NtCreateProfile endp

NtCreateSection proc far
    mov eax, 1Ch
    lea edx, dword ptr [esp+4]
```

```
    int 2Eh
    retn 1Ch
NtCreateSection endp
```

It goes on like this for hundreds and hundreds of functions. Most of the functions in NTDLL.DLL are little more than wrappers around INT 2Eh calls with function numbers in EAX.

Just as there needs to be a way for 16-bit real-mode code running in a DOS application to make a SVC-like call down to the 32-bit protected-mode subsystem code in NTVDM, there also needs to be a way for code running in user-level Ring 3 32-bit protected-mode code to make a SVC-like call down to the NT kernel running at Ring 0. NTDLL uses INT 2Eh instructions to call down to the NT kernel. Naturally, this protected-mode INT 2Eh has nothing to do with the INT 2Eh call that real-mode COMMAND.COM provides as its backdoor.

When NTDLL makes an INT 2Eh, it is handled by NTOSKRNL.EXE, the NT operating system kernel, or by NTKRNLMP.EXE, the multiprocessor version of the NT kernel. These files too can be examined with DUMPBIN or a similar utility. NTOSKRNL exports almost 1000 functions, such as (to pick a bunch at random):

```
CcGetFileObjectFromBcb()
ExQueueWorkItem()               , Ex = General executive routine
FsRtlRegisterUncProvider()      ; Fs = File system
IoAdapterObjectType()           ; Io = I/O subsystem
IoStartNextPacket()
KeWaitForMultipleObjects()      , Ke = Kernel
MmMapIoSpace()                  , Mm = Memory management
NtCreateFile()
NtVdmControl()
ObQueryNameString()             , Ob = Object management
PsThreadType()                  , Ps = Process structure
RtlGetHeapUserValue()           , Rtl = Run-time library (user mode)
SeOpenObjectAuditAlarm()        , Se = Security
ZwReadFile()                    , Zw = Windows NT system service
```

That is what the NT API looks like. It is important to note that the NT DDK *Kernel-mode Driver Reference* and *Kernel-mode Device-driver Design Guide* document some of these NTOSKRNL functions, and that several also are prototyped in DDK header files such as NTDDK.H.

NTOSKRNL exports functions from HAL.DLL, which contains the NT Hardware Abstraction Layer. HAL exports functions from NTOSKRNL. Despite the picture painted in most architectural diagrams of Windows NT, HAL is far from being the only hardware-dependent piece of NT; this is simply a goal.

NT internals is a major topic, and the NT guru deserves its own book, so we will leave the reader dangling here and return to the topic of undocumented MS-DOS.

CHAPTER 5

INTRSPY: A Program for Exploring DOS

by David Maxey

Several [illegible] INTRSPY [illegible] points such as those used by XMS

[illegible] tion, and finally discusses plans for its commercial future

Why a Script-Driven, Event Driven Debugger?

INTRSPY [illegible] interrupt vectors or far call [illegible] events and [illegible] which are generally driven by a user's keystrokes

[illegible] many other [illegible] gram exits unexpectedly because it can't find some configuration file, but the program's error messages don't tell you which file it [illegible] creating, or finding files

[illegible] DOS [illegible]

IBM as part of its Personally Developed Software series is still available (contact Personally Developed Software, Wallingford CT).

What sets INTRSPY apart from other DOS monitoring programs is its use of a *scripting language* for intercepting interrupts. INTRSPY knows very little about any particular DOS or BIOS call. It doesn't know that INT 21h Function 3Dh is the Open File function, it doesn't know that this function takes an ASCIIZ path name of a file to open in the DS:DX register pair, or that if successful, the function returns a file handle in the AX register. Rather than hard-wire such protocol knowledge into the program, INTRSPY's scripting language lets the user provide such knowledge.

The secret is that the program is open-ended. If you want to monitor some undocumented report of DOS that this book doesn't mention, you can. If you want to examine some little-known DOS call's stack, you can do it with a script. Furthermore, because the INTRSPY language includes support for structures, you can produce meaningful output rather than raw register dumps.

INTRSPY is currently for real-mode DOS only. To watch interrupts occurring in protected mode under Windows, you can use the BPINT command in Soft-ICE/Windows or INTRSPY's baby brother for Windows, WINSPY. Windows Spy is in Chapter 4 of *Undocumented Windows*.

A Guided Tour

Let's begin with a quick session with INTRSPY. It makes sense to start with something that doesn't require undocumented DOS stack wizardry. Suppose we are interested in tracking down which files a program opens. One could, of course, disassemble the program or run it under a debugger, but it makes more sense to treat the program as a "black box" and simply see which DOS calls it makes. In other words, in this case we should study the program as a behaviorist rather than a Freudian, psychoanalyst. INTRSPY is perfect for this sort of exploration.

For example, the following commands could be used to find out which files Microsoft C/MASM 6.0 opens when compiling the ever-popular industry-standard HELLO.C program:

```
intrspy
cmdspy /compile fopen.scr
cl hello.c
cmdspy /report
```

The first line loads INTRSPY, which is a memory-resident program. It then uses CMDSPY to compile the INTRSPY script called FOPEN.SCR. As explained below, CMDSPY communicates with the resident INTRSPY program. Then the Microsoft C compiler is run. Finally, the last produces a report, which we also could have set up by directing DOS to redirection as in CMDSPY /REPORT > CLTOD. As for the FOPEN.SCR script itself, Listing 5-1 shows a very simple version which traps only calls to INT 21h Function 3Dh (Open File).

Listing 5-1: FOPEN.SCR (simple version)

```
; FOPEN.SCR
intercept 21h
    function 3dh    ; Open file
        on_entry
            output "OPEN " (ds:dx->byte,asciiz,64)
        on_exit if (cflag == 1)
            samefmt " [FAIL " ax "]"
```

This script instructs INTRSPY to intercept INT 21h and trap all calls to AH=3Dh. Function 3Dh, the DOS handle-based file open function. On entry to the call, INTRSPY should output the string "OPEN " plus the ASCIIZ string pointed to by the DS:DX register pair, a maximum of 64 bytes will be stored. The pointer operator (->) indicates that DS:DX is to be used as a pointer to an area of memory that should be treated as bytes. Sixty-four bytes should be stored and formatted on output as

an ASCIIZ string. On exit from INT 21h AH=3Dh if the carry flag is set, the script tells INTRSPY it should output, on the same line, the string " FAIL " and the value of the AX register enclosed in square brackets. Note in Figure 5-1 how the on_entry clause corresponds to the parameters expected by INT 21h Function 3Dh, and how the on_exit clause corresponds to its possible error return value.

Figure 5-1: The DOS Open Function and a Corresponding INTRSPY Script

```
INT 21h Function 3Dh                                intercept 21h function 3dh
Open File                                           on_entry output "OPEN  "
Call with:
    AH = 3Dh
    AL = access mode
    DS DX -> seg:ofs of ASCIIZ pathname             (ds dx->byte,asciiz,64)
Returns:                                            on_exit
    CARRY = clear if function successful
        AX = handle
    CARRY = set if function unsuccessful            if (cflag  = 1)
        AX = error code                             sameline " [FAIL " ax  "]"
```

The output file INTRSPY goes not directly to your screen but into a results buffer. The default buffer size is 8K. This can be overridden on the INTRSPY command line. For example, INTRSPY /r60000. After running CL HELLO.C, the command INTRSPY REPORT produced the results shown in Figure 5-2.

Figure 5-2: INTRSPY FOPEN Results for CL HELLO.C

```
OPEN  \msc700\bin\CL.EXE
OPEN  \msc700\bin\ms32krnl.dll
OPEN  CON
OPEN  CON
OPEN  C:\msc700\bin\CL.EXE
OPEN  C:\UNDOC2\CHAP5\C13216.EXE [FAIL 2]
OPEN  C:\msc700\bin\C13216.EXE
OPEN  C:\UNDOC2\CHAP5\D15592sy [FAIL 2]
OPEN  C:\UNDOC2\CHAP5\D15592sy
OPEN  C.\UNDOC2\CHAP5\D15592gl [FAIL 2]
OPEN  C.\UNDOC2\CHAP5\D15592gl
OPEN  C:\UNDOC2\CHAP5\D15592ex [FAIL 2]
OPEN  C.\UNDOC2\CHAP5\D15592ex
OPEN  C:\UNDOC2\CHAP5\D15592in [FAIL 2]
OPEN  C:\UNDOC2\CHAP5\D15592in
OPEN  C:\UNDOC2\CHAP5\D15592st [FAIL 2]
OPEN  C.\UNDOC2\CHAP5\D15592st
OPEN  C:\UNDOC2\CHAP5\hello.c
OPEN  C:\UNDOC2\CHAP5\stdio.h [FAIL 2]
OPEN  C:\msc700\include\stdio.h
OPEN  C:\UNDOC2\CHAP5\q23.exe [FAIL 2]
OPEN  C:\msc700\bin\q23.exe
OPEN  C:\msc700\bin\q23.exe
OPEN  D15592g
OPEN  D15592ex
OPEN  D15592in
OPEN  D15592st
OPEN  hello.obj [FAIL 2]
OPEN  hello.obj
OPEN  D15592sy
OPEN  C:\UNDOC2\CHAP5\D15592lk [FAIL 2]
OPEN  C:\UNDOC2\CHAP5\D15592*.*
OPEN  C:\UNDOC2\CHAP5\link.exe [FAIL 2]
OPEN  C:\msc700\bin\link.exe
OPEN  C:\msc700\bin\link.exe
OPEN  C:\msc700\bin\link.exe
```

```
OPEN  C:\msc700\bin\link.exe
OPEN  C:\msc700\bin\link.exe
OPEN  015592tk
OPEN  hello.obj
OPEN   msc700\lib\OLDNAMES.lib
OPEN  \msc700\lib\SLIBCE.lib
OPEN  \msc700\lib\OLDNAMES.lib
OPEN  C:hello.exe [FAIL 2]
OPEN  C:hello.exe
OPEN  C:\UNDOC2\CHAP5\CMDSPY.EXE
```

When you execute the compiled DEFLOC.ASM32KRNL.DLL is a hacked Win32 portable executable (PE) file. The temporary files with the .exe, .lnk, and .tmp suffixes relate to different compiler passes. Some of the .tmp files contain expressions, global optimization, local optimization, and scope.

Perusing the Microsoft C 6.00 compiler's /qc option reveals that the /qc option invokes a quick compile. Instead of the compiler's normal two-pass compile with full optimizing, compile the INTRSPY results as shown in Figure 5-3 and Listing 5-2. Now make this /qc switch's sister, Uncle Scratch. /qc does not have the same effect in MSC 7.0.

Figure 5-3 INTRSPY FOPEN Results for CL /QC HELLO.C

```
OPEN qcc.exe [FAIL 0002]
OPEN hello.obj
OPEN hello.c
OPEN c:\c600\include\stdio.h
OPEN 0072811k [FAIL 0002]
OPEN link.exe [FAIL 0002]
OPEN c:\c600\bin\link.exe
OPEN 0072811k
OPEN hello.obj
OPEN c:\c600\lib\SLIBCE.lib
OPEN C:hello.exe
OPEN C:hello.exe
OPEN C:\DOS\COMMAND.COM
```

When you execute the compiled DEFLOC.ASM32KRNL.DLL version of the INTRSPY script we have created a file open trace that is only 10 lines long. Between these files lies more than 1,000 lines of code and more importantly, a good several hours of programmer's time. Use this tool to help you debug your C, assembly language, or Pascal programs.

Note that DOS 4.x SCR files contain valuable documentation. Data logging of this type is invaluable when you're trying to figure out what system activity is DOS-related and what is not. For example, the FOPEN.SCR file opens files such as IN.2.c:\AUTOEXEC.BAT, which is DOS's Open and AL=6Ch Extended Open/Create.

We can use the FOPEN.SCR to trap some additional DOS functions as shown in the beefed-up version of FOPEN.SCR in Listing 5-2. We also show the DOS command lines with which programs are EXECed. FOPEN.SCR uses the INTRSPY.STRUCTURE that represents the parameter block used by the DOS EXEC function. It also uses a STRUCTURE to represent the part of the DOS File Control Block that's interested in.

Listing 5-2: FOPEN.SCR Watches File Open, Create, Find, and Exec

```
; FOPEN.SCR
structure param_blk fields
    env_seg (word,hex)
    args (dword,ptr)

structure fcb fields
    drive_num (byte,char)
    filename (byte,char,8)
    ext (byte,char,3)
```

```
    ; etc.
intercept 21h
    function 0Fh    ; Open File with FCB
        on_entry
            output  FCBOP " (ds:dx->fcb.filename) ".  (ds dx->fcb ext)
        on_exit if (al == 0FFh)
            sameline " [FAIL]"
    ; ---------------------------------------
    function 3ch    ; Create File
        on_entry
            output  CREAT   (ds.dx->byte,asciiz,64)
        on_exit if (cflag == 1)
            sameline " [FAIL   (ax, dec) "]"
    ; ---------------------------------------
    function 3dh    ; Open File
        on_entry
            output "OPEN  " (ds:dx->byte,asciiz,64)
        on_exit if (cflag == 1)
            sameline " [FAIL " (ax, dec) "]"
    ; ---------------------------------------
    function 4bh    ; Execute Program
        subfunction 00h
            on_entry
                output "EXEC  "
                    (ds:dx->byte,asciiz,64)                    , program
                    (es bx->param_blk.args->byte,pascal,128) ; cmdline
            on_exit if (cflag == 1)
                sameline " [FAIL " (ax, dec)  "]"
    ; ---------------------------------------
    function 4eh    ; Find First File
        on_entry
            output "FIND  " (ds dx->byte,asciiz,64)
        on_exit if (cflag == 1)
            sameline " [FAIL " (ax, dec) "]"
    ; ---------------------------------------
    function 6Ch    ; Extended Open/Create
        on_entry
            output "XOPEN " (ds si->byte,asciiz,64)
        on_exit if (cflag == 1)
            sameline " [FAIL " (ax, dec)  "]"
```

The first INTRSPY STRUCTURE statement corresponds to the first two fields (the only ones that matter here) of the parameter block that INT 21h function 4Bh Subfunction 00h expects from the ES:BX register pair. FOPEN SCR outputs the DOS command line for the first 64 bytes of it, with this expression

```
(es:bx->param_blk.args->byte,pascal,64)
```

This indicates that the ES:BX pair points to an area of memory that should be treated as a param_blk structure, and that we are interested in the args field. FOPEN SCR then uses another arrow (->) to indicate that args, which was defined as a dword here, points to a string. A Pascal designation, which reflects how strings are stored by Pascal, is different from ASCIIZ, in that its first byte is a length count. This corresponds exactly with the command tail used by MS-DOS.

Now, of course, INTRSPY produces even more output, a small fragment of which is shown in Figure 5-4, describing the actions generated by the simple command CL HELLO.C.

Figure 5-4: Detailed INTRSPY FOPEN Results for CL HELLO.C

```
FIND  cl.??? [FAIL 18]
FIND  \bin\cl.??? [FAIL 18]
FIND  \dos\cl.??? [FAIL 18]
FIND  \borlandc\bin\cl.??? [FAIL 18]
```

```
FIND  \watcomc\bin\cl.??? CFAIL 183
FIND  \msc700\bin\cl.???
OPEN  \msc700\bin\CL EXE
EXEC  \msc700\bin\CL EXE hello.c
OPEN  \msc700\bin\ms32krnl.dll
OPEN  CON
OPEN  CON
    lots of OPENs, as in Figure 5-2
OPEN  C \msc700\bin\q23.exe
OPEN  C \msc700\bin\q23.exe
EXEC  C:\msc700\bin\q23.exe
OPEN  015592gl
OPEN  015592ex
    more OPENs, as in Figure 5-2 .
OPEN  C \msc700\bin\link exe
OPEN  C \msc700\bin\link exe
EXEC  C \msc700 bin\link exe aa"015592ll"
OPEN  C:\msc700\bin\link exe
OPEN  C \msc700\bin\link exe
    yet more OPENs, as in Figure 5-2
OPEN  \msc700\lib OLDNAMES clB
OPEN  C hello exe
FIND  cmdspy.???
CREAT hello2.log
OPEN  C:\UNDOC2\CHAP5\CMDSPY EXE
EXEC  C:\UNDOC2\CHAP5\CMDSPY.EXE report
```

The first thing Figure 5-4 shows is that before the actual execution of CL.EXE itself, COMMAND.COM must first load it. The series of linked calls to the DOS Load and Exec function show COMMAND.COM looking along the PATH in many subdirectories before it finally finds CL.EXE. If you were going to be using Microsoft C a lot, it would probably be a good idea to optimize your PATH by moving C:\MSC\BIN forward a little.

INTRSPY can be licensed as a protocol analyzer for PC software interrupts, where INTRSPY itself only knows about raw interrupts, registers, and memory, and where the user's scripts impose the necessary higher level interpretation to understand what is actually going on.

Device Drivers

INTRSPY also provides a script driven approach to watching block and character mode device drivers using the same INTERCEPT command used to hook interrupts.

```
INTERCEPT STRATEGY( devname")    , Character mode device
INTERCEPT INTERRUPT("d:")        ; Block mode device
```

Block mode devices support data transfers to and from devices a block at a time, usually for random access storage devices such as hard disks and are identified by a drive letter. Character mode devices drivers provide stream (character by character) access to devices such as communications channels. They are also used to provide interfaces to system facilities such as XMS that may need to get invoked each time a program wants to allocate memory. DOS includes built in block mode device drivers for the floppy and hard disk devices, for example, while HIMEM.SYS implements a character mode device driver for managing XMS extended memory. The names of these character mode drivers are displayed by programs such as DEV from Chapter 7.

Listing 5-3, DDSTR, shows how you might record device driver calls to any device driver. Note that while you can monitor calls to both the Strategy and Interrupt entry points to the device driver, generally it is only useful to monitor the Strategy routine. DOS does not exploit the separation in drivers between Strategy and Interrupt, as soon as DOS calls the Strategy routine, it calls the Interrupt routine. Unlike operating systems such as OS/2 and NT, DOS does not provide overlapped, asynchronous I/O.

Listing 5-3: DD.SCR Watches Calls to Device Drivers

```
; DD.SCR -- watch any device driver named on command line
; CMDSPY COMPILE DD C
; CMDSPY COMPILE DD EMMXXXX0

structure requ fields
    len (byte, hex)
    subunit (byte, hex)
    cmd (byte, hex)
    status (word, hex)
    ; other stuff depends on packet

intercept strategy( %1 )
    on_entry
        if ((es:bx->requ.cmd) == 0) output "00 - init"
        if ((es bx->requ cmd) == 1) output "01 - media check"
        if ((es bx->requ cmd) == 2) output  02   build bpb"
        if ((es bx->requ  md) ==  3) output  03 - ioctl input"
        if ((es bx->requ cmd) == 4) output  04 - input
        if ((es bx->requ cmd) == 5) && (#5 == 0)    ; often a lot of these
         output "05 - nondestruc input"
        if ((es bx->requ cmd) == 5)
         incr #5
        if ((es bx->requ cmd) == 6) output "06 - input status"
        if ((es bx->requ cmd) == 7) output "07 - input flush"
        if ((es bx->requ cmd) == 8) output  08 - output
        if ((es bx->requ cmd) == 9) output "09 - output w/verify"
        if ((es bx->requ cmd) == 0Ah) output "0A - output status"
        if ((es bx->requ cmd) == 0Bh) output "0B - output flush"
        if ((es bx->requ  md)    0Ch) output  0C - ioctl output"
        if ((es bx->requ cmd)    0Dh) output  0D   device open"
        if ((es bx->requ cmd) == 0Eh) output  0E   device close"
        if ((es bx->requ cmd) == 0Fh) output  0F   removeable media"
        if ((es bx->requ cmd)    10h) output  10   output until busy"
        , 11h and 12h are missing from DOS 5 Programmer's Reference
        if ((es bx->requ cmd)    11h) output "11 - stop output"
        if ((es bx->requ cmd)    12h) output  12 - restart output
        if ((es bx->requ cmd) == 13h) output  13   generic ioctl"
        if ((es.bx->requ cmd)    14h) output  14 - unused
        if ((es bx->requ cmd) == 15h) output  15 - unused??
        if ((es bx->requ cmd) == 16h) output  16   unused"
        if ((es bx->requ cmd) == 17h) output  17 - get logical device
        if ((es bx->requ cmd) == 18h) output  18 - set logical device
        if ((es bx->requ cmd     19h) output  19    octs query
        if ((es.bx->requ cmd) > 19h) output (es bx->requ.cmd)   - UNKNOWN"
        , could also handle CD-ROM driver commands
; intercept interrupt("%1")
,   on_entry
,       output "Interrupt entry point patted"
run "%2 %3 %4 %5 %6 %7 %8 %9"
report
```

This script introduces several additional features of the INTRSPY language. The "%1" in the script operates as the script would if it were a batch file: it acts as a parameter specified on the command line after the script name. Here, the script expects to be supplied the RUN statement necessary to run a certain device driver. A DOS command line except that in the INTRSPY script RUN is a help reduce the amount of typing required. Cross-reference programs you are very interested in. CMDSPY runs the command. Last, the REPORT statement causes compiling the script. Finally, the REPORT statement is similar to running CMDSPY REPORT.

To see what commands are sent to the A: block driver during a simple command such as VOL A:, you could issue the following at the DOS command prompt:

```
C:\UNDOC2\CHAP5>cmdspy compile dd a  "command /c vol a:" > tmp.tmp
```

This kitchen sink command compiles DDSCR to watch drive A: issues the internal command, VOL A: (where COMMAND.COM and redirects CMDSPY's output to TMP.TMP. The output would look something like that shown in Figure 5-5. The first line is output from the VOL command itself; the rest of the output comes from CMDSPY.

Figure 5-5: DD.SCR Output for VOL A:

```
 Volume in drive A has no label
(Handler for calls to 0070-06F5 was already stopped.)
File: DD.SCR
Line 12: intercept strategy("a:")
                            ***
Warning - Same block device driver supports multiple drives
7214 bytes of code generated for 'a:' driver strategy script

Running program: C:\DOS\command.COM. .
Run completed.

05 - nondestruc input
01 - media check
04 - input
04 - input
04 - input
04 - input
04 - input
04 - input
04 - input
04 - input
01   media check
04   input
13   generic ioctl
01 - media check
04 - input
04 - input
04 - input
08 - output
08 - output

Counter #5  : 2
All other counters zero.
```

Another example of INTRSPY that DDSCR uses is a counter. There will often be so many calls to a driver's strategy routine for nondestructive input that the INTRSPY resets buffer would immediately fill up with lines of text reporting a line of input for each one. Therefore, DDSCR only displays the first nondestructive input request and increases all the rest only to increment a counter—INC #5 in Listing 5-3.

System counters are variables identified by #1 through #10. Each is a 32-bit value that may be incremented—INC—decremented—DEC—or reset to zero—ZERO—within a script. They may also be compared in IF statements and used as elements in DO-UNTIL or SAMPLE-INT statements. We packed #5 here simply because it matches the command number for nondestructive input. At the end of an INTRSPY report, CMDSPY displays any active counters. In Figure 5-5, we can see that there were two calls; checking in several cases there will be thousands.

With most character-mode device drivers such as XMSXXXX0, you won't see much activity. As noted earlier, these are often coded as device drivers only to get them installed early for use by other device drivers. In the case of XMS in particular, Microsoft has a true device driver version of HIMEM.SYS called XMSMMGR.EXE—see Chapter 11 for Windows 3.1 and 3.0—which DOS loads when the user doesn't have HIMEM.SYS or another XMS driver installed. For some of these drivers *do* deal with device driver packets, part or all of the generic IOCTL calls. For example, EMMXXXX0 and 386MAX$$ have generic IOCTL calls that

are used by Windows. For these, on the other hand, it is probably easier to watch calls to INT 2Fh AH=43h rather than inspect the lower-level device driver packets.

Watching XMS

While interrupts and device driver entry points account for much of the communications between software and the PC, it is by no means all. To use XMS, for example, a program makes an initial call to INT 2Fh AX=4310h and the address returned in ES:BX is then used for all subsequent calls to XMS services. Simply intercepting INT 2Fh and watching for AX=4310h will not get you very far.

XMS calls can be intercepted using INTRSPY scripts using another form of the INCLUDE command. In this case, the interrupt number or device driver name is replaced by the special keyword XMS, as seen in the XMSWATCH script in Listing 5-4.

Listing 5-4: XMSWATCH.SCR

```
; XMS.SCR

structure move_fields
    len (dword,hex)
    src (word,hex)
    src_ofs (dword,hex)
    dest (word,hex)
    dest_ofs (dword,hex)

intercept xms
    function 0 on_entry output  "XMS 00 - get xms version number"
    function 1 on_entry output  "XMS 01   request HMA " dx
    function 2 on_entry output  "XMS 02 - release HMA"
    function 3 on_entry output  "XMS 03   global enable A20"
    function 4 on_entry output  "XMS 04   global disable A20"
    function 5 on_entry output  "XMS 05 - local enable A20"
    function 6 on_entry output  "XMS 06 - local disable A20"
    function 7 on_entry inc  #1 ,, Query A20 state   Too many of these!
    function 8 on_entry output  "XMS 08   query free extended memory"
               on_exit same line    =>    ax
    function 9 on_entry output  "XMS 09   allocate extended memory   dx
    function 0Ah on_entry output  "XMS 0A - free extended memory   dx
    function 0Bh on_entry output  "XMS 0B - move extended memory
               (ds * .>move_len)
                 from   (ds:s .>move_src) ":" (ds:si.>move_src_ofs)
                 to " (ds:si->move_dest) ":" (ds:si.>move_dest_ofs)
    function 0Ch on_entry output "XMS 0C   lock extended memory   dx
    function 0Dh on_entry output  "XMS 0D   unlock extended memory   dx
    function 0Eh on_entry output  "XMS 0E - get handle info
    function 0Fh on_entry
                 output "XMS 0F - realloc extended memory " dx "," bx
    function 10h on_entry output  "XMS 10 - request UMB   dx
    function 11h on_entry output "XMS 11 - release UMB   dx
    function 12h on_entry output "XMS 12 - realloc UMB"

#include "prog"
```

Looking at Listing 5-4, you can see that XMS version 2.0 specific calls will require much more effort to decode, including the additional calls for 32-bit calls.

The last line of XMSWATCH.SCR shows another INTRSPY feature. Common scripts can be included using the INCLUDE statement. The example might use #include to load Pascal-like PROG.SCR, as shown in Listing 5-5, records the start of program execution. Later in the chapter, a more extensive version, EXEC.SCR, provides an INTRSPY machine word. In its PROG.SCR form, it is used in a way that you will include in many of your scripts since it indicates exactly what program is the criteria your primary script is recording actual features of a particular program.

Listing 5-5: PROG.SCR

```
; PROG.SCR
intercept 21h function 4bh on_entry
    output "-------------------------   ----------------"
    output (ds:dx->byte,asciiz,64)
```

using XMSWATCH while Windows is starting up. The XMSWATCH results show, for example, that Windows grabs all free extended memory. It calls XMS function 8 to query the size of the largest block of available extended memory and then calls XMS function 9 to allocate that largest available block.

Later, Windows repeats this sequence of calls to XMS function 7. Query A20 State a number of times. Again, Windows typically calls this function thousands of times in a very brief period. Logging the occurrence of each of these would produce a very monstrous report.

Most of the XMSWATCH output will be devoted to XMS function 0Bh, Move. In the report for a single Windows session, there were 4,000 lines of output, 3,950 of which were function 0Bh calls. Each of these calls represents a request to move a block of data using the workhorse function of the XMS interface. XMSWATCH shows the source and destination addresses as xxxx:yyyyzzzz. If xxxx is zero, it represents a conventional memory address yyyy:zzzz. Otherwise, xxxx is an extended memory handle and yyyyzzzz is a 32-bit offset into the extended memory block. EMM.

Another thing you can expect the XMS driver to be doing for a brief period during the Windows load process is because Windows takes over responsibility for XMS and because, as a result, it does some housekeeping. INTRSPY runs temporarily into trouble when Windows makes the transition to 386 Enhanced mode.

Internally, INTRSPY knows that Windows is starting up through the use of Int 2Fh function 16h. Windows provides the Windows Among other things, this interface provides hooks to allow TSRs to not only be notified of startup and shutdown of Windows, but to perform many necessary preparations and cleanup. Windows must load almost 1 Mb of data from disk. The MASM example that will be presented in Chapter 9 uses this interface to synchronize operations between MS-DOS and Windows.

Normally, during the Windows startup code, when it is still in real mode, it hooks Int 21h and then executes Int 2Fh. Since the 386 Enhanced mode and informs TSRs that the Windows environment is starting. Windows uses a pair of calls, subfunctions 09h and 0Ah, to notify TSRs that entered protected mode. Knowing when Windows has completed its protected mode initialization is important. INTRSPY disables the XMS hook during startup and shutdown to allow the V86MMGR module of Enhanced mode Windows to execute a WRPT instruction at the XMS entry point. This instruction will generate an exception, which Windows traps to receive control. INTRSPY then reinstalls its own patch, allowing it to intercept XMS calls before passing the request to Windows.

Dynamic Hooks

NTRSPY also provides the capability of watching calls to any interrupt vector, not just XMS. In fact, XMS is simply a special case of a general-purpose hook. You may specify your own hooks for other addresses as well, with the exception of Int 2Fh. This feature is very powerful and allows the trapping of callbacks.

Using the INTRSPY HOOK facility, for example, a script can be written to watch the completion of NetBIOS requests. In NetBIOS, an application can communicate asynchronously over the network. That is, a calling application can request that NetBIOS goes about the business of sending or receiving data. Once an application has issued a request by specifying a post routine as one of the parameter blocks in the NetBIOS control block, NetBIOS is passed to Interrupt 5Ch when requesting a NetBIOS network service. At the completion of whatever task has been requested, NetBIOS calls the post routine, notifying the application.

The most significant difference between the previous INTERCEPT commands and the entry point alternative is that the address that is to be intercepted is supplied, not at compile time, but as a

result of another event. This is achieved using a HOOK statement with the same identifier, as shown in Listing 5-6 (NETBIOS.SCR).

Listing 5-6: NETBIOS.SCR

```
; NETBIOS.SCR
structure ncb fields
    cmd             (byte)
    rc              (byte)
    loc_sessno      (byte)
    name_no         (byte)
    buffer          (dword,ptr)
    buflen          (word,dec)
    dest_name       (byte,char,16)
    srce_name       (byte,char,16)
    rto             (byte, dec)
    sto             (byte, dec)
    post_routine    (dword,ptr)
    adap_no         (byte)
    cmd_rc          (byte)
    reserved        (byte,hex,14)
intercept post_routine
    on_entry
        output  ""
        output "-------------------------------------"
        output "Post routine triggered for NCB at " es ":" bx
            " - completed " (es:bx->ncb.cmd_rc)
intercept 5ch
    on_entry
        output  ""
        output  "*************************************"
        output  NCB at   es     bx   submitted" (es bx->ncb)
        if ((es bx->ncb cmd  > 127)
            output  Command is NOWAIT
        if ((es bx >ncb cmd  > 127) && ((es bx->ncb post_routine) != 0)
            hook post_routine = (es:bx->ncb.post_routine)
            sameline  - Post routine used
    on_exit
        output  On exit AL is   a
```

The first INTERCEPT statement refers to an identifier post_routine. When the script is compiled, there is no address associated with post_routine since the NCB whose post routine we want to trap, has not yet been created. However, our second INTERCEPT statement is watching NetBIOS interrupts (INT 5Ch). When an application program interrupts NetBIOS to submit the NCB for processing, the intercept can determine if a post routine has been specified (that is, the POST field in the supplied NCB structure is not NULL). If a post routine has been specified, the HOOK statement uses the address of the POST field as the address to be watched by the post_routine intercept.

INTRSPY's ability to treat multiple intercepts differently from the one hand and entry point identifiers on the other can be likened to the difference between static and dynamic linking. Static linking establishes the addresses for function calls between modules when a program is built. Dynamic linking only establishes those inter-module, logical addresses at run time. In the same way, INTRSPY links interrupt and device driver INTERCEPT statements to the appropriate addresses at compile time but links a post_routine identifier in a script to the appropriate address when the associated HOOK statement within another INTERCEPT is invoked.

In Listing 5-6, notice how an entire NCB structure resulted from the single statement ES BX sNCB. When so asked, INTRSPY will take care of displaying every field in a structure, including the field's name. The resulting output can be seen in Figure 5-6, which shows output from NETBIOS.SCR for a single NetBIOS command. As can be seen from the NCB.CMD field, the

command was 42h (this is a Send Broadcast Datagram 22h with the no wait bit 80h) set. The NCB was located at 0CDD:0DDA. The actual data to send was located at 0CDD:0048 (NCB_BUFFER +48 decimal bytes were to be sent (NCB_BUFLEN). We could of course have displayed the contents of this buffer as well.

Figure 5-6. Output from NETBIOS.SCR for a NetBIOS Command

```
NCB at 0CDD:0DDA submitted
NCB.CMD                         42
NCB.RC                        : 00
NCB LOC_SESSNO                : 00
NCB NAME_NO                   : 02
NCB.BUFFER                      0CDD:0048
NCB BUFLEN                      18
NCB DEST_NAME
NCB.SRCE_NAME
NCB RTO                       : 0
NCB STO                       : 0
NCB.POST ROUTINE              : 0868:003B
NCB ADAP_NO                     00
NCB CMD_RC                    : 00
NCB RESERVED                    00  00  00  00  00  00  00  00  00  00  00  00
 00  00  00
Command is NOWAIT - Post routine used
                  .    ---- ----------
Post routine triguered for NCB at 0CDD:0DDA - completed OO
On exit AL is 00
```

Since the goal of this example is to illustrate the INTRSPY HOOK statement, the important thing in Figure 5-6 is the end where the post routine was called at some later point for the initial no wait asynchronous send broadcast datagram command. As can now see, the completion code NCB.CMD_RC (was zero, indicating success.

The next to last example of the HOOK functions use to watching callback functions, not DOS services. The final caveat associated with this use is at least the NetBIOS context. The problem as always may not exist when you are using Windows enhanced mode. Since an application running in a DOS box may not be in memory at the precise moment that its NetBIOS event completes, a virtual device driver (VNETBIOS.VXD) is provided to undertake, among other things, the virtual memory manipulation and task switching necessary to synchronize the VM and the callback. In order to do this the INT statement at the application issuing the NCB is intercepted by the VxD and the post routine address is replaced with the protected mode address of a thunk that will be invoked before the post routine is called. Additionally the buffer address is converted to the address of a protected mode locked buffer, and the real mode callback can be called.

The above should be a matter you might think given that INTRSPY is running in the same DOS window and so all interrupt purposes replaces the application temporarily. Using the ON ENTRY clause you might also expect to pick up any addresses before they are modified. Unfortunately not. Windows gets there first, as you'll see in the VRPI routine, from V86 breakpoint and passes control back to the VM's real mode interrupt handler routine. Thus even in the ON ENTRY clause we are too late. This all means that in a DOS box, hooking a NetBIOS callback will not lead to the desired results and will in all likelihood crash the VM.

Note the similarity here to other earlier problems with XMS. For a program like INTRSPY Windows enhanced mode is a tough application with which to be compatible.

INTRSPY User's Guide

INTRSPY is actually two programs: INTRSPY.EXE and CMDSPY.EXE, whose operating instructions follow.

Using INTRSPY.EXE

The following command is used to run INTRSPY.EXE:

```
INTRSPY [-rnnnn] [-?]
```

where -rnnnn specifies the amount of memory INTRSPY is to allocate for compiled script and result storage; default is 8K. For example, the following command runs INTRSPY with an allocation of 24,000 bytes of code and results space:

```
C:\UNDOC2\CHAPS>INTRSPY -r24000
```

Using CMDSPY.EXE

The following command is used to run CMDSPY.EXE:

```
CMDSPY  [COMPILE [d:][path]inputfile[.ext] [param-1 [param-2 ...]]]
        [REPORT]
        [RESTART]
        [FLUSH]
        [STOP]
        [UNLOAD]
```

where

- COMPILE compiles a script and instructs INTRSPY to begin monitoring interrupts and entry points as well as storing results specified in inputfile.ext, which contains script source in the format described below. Any currently active script is stopped, and the results area is flushed. If the extension is omitted, .SCR is assumed. For example, the following DOS command line compiles the script TEST.SCR:

  ```
  C:\UNDOC2\CHAPS>CMDSPY COMPILE TEST
  ```

- REPORT instructs INTRSPY to return the results accumulated since the script was compiled or since the last time CMDSPY FLUSH was issued (see below). CMDSPY formats the results in the results buffer as specified in the current script and writes them to STDOUT. The display can be redirected to a file. For example:

  ```
  C:\UNDOC2\CHAPS>CMDSPY REPORT > TEST.LOG
  ```

- STOP instructs INTRSPY to stop monitoring interrupts and entry points but to preserve the results area.
- RESTART instructs INTRSPY to restart monitoring interrupts and entry points after a STOP or REPORT command on the basis of the currently compiled script.
- FLUSH instructs INTRSPY to reset the results area but to leave the current script active.
- UNLOAD instructs the INTRSPY TSR to *attempt* to uninstall itself from memory. Any active script is stopped. There are circumstances under which INTRSPY cannot be unloaded.

Script Language

The script language allows the following constructs:

- INCLUDE, which includes another input file
- STRUCTURE, which defines a data structure
- INTERRUPT, which specifies an interrupt number, device driver strategy or interrupt routine, or an entry point number to be used with a HOOK statement. It also specifies optional

function and subfunction numbers or ranges together with the entry and exit processing to be done when the intercept is triggered
- RUN, which allows a DOS program to be EXECed from within the script and a built-in debugger to be used within intercepts
- GETNEXT, which allows interrupts to be generated internally to obtain an address to be associated with an entry point identifier
- REPORT, FLUSH, STOP, and RESTART, all of which work exactly like their command-line counterparts

Syntax

A script file's exact syntax is fairly flexible. All white space is ignored except within literal strings used for results output, function and subfunction numbers may be used for readability or lack thereof, as the user sees fit. Extra parentheses are allowed, and both C-style comments, which begin with a semicolon anywhere on a line, and C++-style comments, which begin with "//" can appear anywhere in a script. Text and arguments are replaceable from the DOS command line. The following is thus a valid INTRSPY script:

```
; INTERCEPT.SCR
intercept %1
    function %2
        %3 %4 %5 %6 %7 %8 %9
```

This script would be useful for one-shot queries that didn't deserve their own separate scripts, for example:

```
C:\>intdspy compile intercept 21h 52h on_exit output es:bx
```

The simplest possible valid INTRSPY script is this:

```
; SCRIPT.SCR
%1 %2 %3 %4 %5 %6 %7 %8 %9
```

Text equivalent to the entire script is placed on the DOS command line:

```
C:\>intdspy compile script intercept 21h function 52h on_exit output es:bx
```

INCLUDE Syntax

The following syntax is used for INCLUDE statements:

```
INCLUDE [d:][path]ingfile[.ext] [param-1 [param-2 ...]]
```

This syntax includes the special file and substitutes parameter 1, parameter 2, and so forth, in the source for the strings %1, %2, ..., respectively, where found. If the extension is omitted, .SCR is assumed. Some examples:

```
include %1              ; include script named on command line
include "foo"           ; include foo.scr
include foo %1          ; include foo.scr, passing arg from cmdline
include foo bar"        ; include foo.scr, passing arg "bar"
```

STRUCTURE Syntax

Some example structures, such as param_blk and fcb in Listing 5-2, FOPEN.SCR, and regs in Listing 5-4, FDD.SCR, were shown earlier.

The formal syntax for STRUCTURE first defines a *field definition* as:

```
field-type [,field-disp-type [,field-dup]]
```

where:

- *field type* can be BYTE, WORD, DWORD, or a previously defined structure name

- *field disp type* can be HEX, BIN, DEC, OCT, PTR, CHAR, PASCAL (a string with the count as its first byte), ASCIIZ (a zero-terminated string), DUMP (a combination of HEX and ASCII), or STRUCT (a field type was a structure name).
- *field dup* is the number of elements if the field should be treated as an array or the length of the field is for example, a string. In the case of a field being defined with a structure definition, field dup may be a numeric literal or one of the predefined constants. In the case of a definition statement's comparison element, see INTERCEPT's syntax, field dup may also refer to a register (e.g., 8 reg16 reg). Then STRUCTURE syntax looks like this:

```
STRUCTURE struct-name FIELDS
     field-name1 (field-definition)
    [field-name2 (field-definition)]


    [field-nameN (field-definition)]
```

Note that struct name must be a unique structure identifier, and that field name must be unique within struct name. There are thirty significant characters for both struct name and field name, and indeed for any INTRSPY symbol. This number should be adequate for almost any application.

INTERCEPT Syntax

Many examples of INTERCEPT statements were presented in the first portion of this chapter, but as now formally listed, INTERCEPT

To begin with, we can define an intercept element as an interrupt number, a device driver strategy routine, an interrupt routine, or an entry point identifier. For example:

```
INTERCEPT 21h                ; intercept an interrupt
INTERCEPT STRATEGY( foo )    ; intercept device driver Strategy routine
INTERCEPT INTERRUPT( foo )   ; intercept device driver Interrupt routine
INTERCEPT hook_proc          ; intercept entry point identifier (see below)
```

Then, define an *output element* as

```
REGS or
reg_or_flag or
(reg_or_flag, field-disp type) or
#counter or
(#counter, field-disp-type) or
"string literal" or
(segval+/-seg_adjust ofsval[additional-offset]->memory-reference) or
predefined-constant or
(predefined-constant, field-disp-type)
```

where

- *reg or flag* is the name of an 8- or 16-bit register or a flag.
- *a flag* is identified by ALL, AC, where AC can be one of the following: D (direction), I (interrupt), T (trap), S (sign), Z (zero), A (auxiliary), P (parity), or C (carry). For example, CLAC or ALAC.
- *#counter* consists of a 16-bit or 32-bit count register identified by #1 through #16.
- *seg val* is a segment value, which can be a variable or built-in constant.
- *seg adjust* is an optional numeric constant to be added to or subtracted from the segment value. For example, es:10 >mcb).
- *offset* is any type of memory constant or built-in constant.
- *additional-offset* is an optional numeric literal increment or decrement. For example, [es:bx+ 12] >bst -31).
- *memory reference* is one of the following:
  - BYTE, WORD, DWORD, field disp type, field dup, with defined in STRUCTURE above.

- ▫ struct
- ▫ struct field
- ▫ struct.dword field >memory reference, where dword field means that the field to be used as a pointer must have been defined as DWORD struct and field must be predefined

- *predefined constant* is one of those defined in the section "Predefined Constants", below

Define an *action statement* as one of the following:

- OUTPUT output element, output element, output element [,], which starts on a new line
- SAMELINE output element, output element, output element [,], which attempts to append elements to an existing line of output
- NEARASM reg8 name, which outputs raw ASCII characters from the 8 bit register specified
- DEBUG, which, if the intercept occurs during a RUN statement, enters a pop up debugger
- INCR #counter, which increments the specified 32 bit count register
- DECR #counter, which decrements the specified 32 bit count register
- ZERO #counter, which resets the specified 32 bit count register to zero
- HOOK entry point identifier, hook spec, where [,] may be replaced by the word 'TO', and hook spec may be [register or segment:reg adjust.ofsval additional offset >memory reference, where memory reference may not include a bead dup type or field dup

Define a *test-clause* as

```
(operand operator operand)
```

where operand may be a

```
reg or flag or
#counter or
(segvalue/ seg-adjust.ofsval[additional offset] >memory-reference) or
predefined-constant
```

where memory reference is one of the following:

- BYTE, WORD, DWORD
- struct.field, where field must be defined as a non dup BYTE, WORD, DWORD
- struct.dword field >memory reference, where dword field means that the field to be used as a pointer must have been defined as DWORD struct and field must be predefined

and where operator may be = equal, <> not equal, > greater than, >= greater than or equal to, < less than, or <= less than or equal to.

Next define an *if clause* as follows:

```
IF test-clause [AND test-clause [OR test clause [ ... ]]]
    [action-statements]
```

where && may be used interchangeably with AND, and || may be used interchangeably with OR.

Add the two keywords ON_ENTRY and ON_EXIT to describe pre- and post processing of an intercept.

Finally, the two additional keywords FUNCTION and SUBFUNCTION provide a shorthand and self documenting form of IF AH == nn and IF AL == nn. However, those tests would likely produce incorrect results at the post processing stage, since AX may have been modified, so the FUNCTION and SUBFUNCTION keywords recall the values that AH and AL had on entry to the intercept.

```
FUNCTION ah-value
    SUBFUNCTION al-value
```

Then, INTERCEPT syntax looks like this:

```
INTERCEPT [intercept-element]
    [action-statements]
    [test clauses]
    [FUNCTION fnctn-number [fnctn-number . .]
        [action-statements]
        [test-clauses]
        [SUBFUNCTION sfnctn-number [sfnctn-number  . ]
            [action-statements]
            [test-clauses]
                [ON_ENTRY
                    [action-statements]
                    [test-clauses]]
                [ON_EXIT
                    [action-statements]
                    [test-clauses]]]
        [SUBFUNCTION sfnctn-number [sfnctn-number  . ]

                .
                .  ]
    [FUNCTION fnctn-number [fnctn-number ... ]
            ,

            .  ]
```

Although the ON_ENTRY and ON_EXIT keywords are shown within the scope of the SUBFUNCTION level in the nested block hierarchy, they need not be; they could have been shown at a higher level below INTERCEPT with FUNCTION and SUBFUNCTION as lower levels in that hierarchy. For example

```
INTERCEPT intercept-element
    ON_ENTRY
        FUNCTION fnctn-number
          .. etc  ..
```

GENERATE Syntax

The GENERATE construct allows an interrupt to be generated from within a script. This allows scripts to be self-contained (see INTDFENT.SCR Listing 5.8). Without it, some other program must be run to generate the wanted interrupt.

The GENERATE construct shares some of the INTERCEPT syntax. There is an ON_ENTRY section and/or an ON_EXIT. The difference is that if GENERATE, one or the other section is required. The ON_ENTRY clause allows for the setting up of registers for the interrupt, and the ON_EXIT clause exists to allow for the use of only one statement: the HOOK command referred to in the INTERCEPT syntax.

The syntax of the ON_ENTRY clause, where hook specs are defined in the INTERCEPT section, is simple:

```
ON_ENTRY
    reg = value [, reg = value[, reg = value]]
```

The syntax of the ON_EXIT clause is

```
ON_EXIT
    HOOK entry point-identifier = hook-spec
    [HOOK entry point-identifier = hook-spec]
    ...
```

RUN Syntax

The RUN syntax looks like this:

```
RUN "[d:][path]program[.ext] [parm1 [parm2  ..]]"
```

The command is executed first as an EXE and then a COM file is searched for, either in the specified path or the DOS search PATH if both drive and path are omitted. Substitute parameters, %1, %2, and so forth, in the source for the strings %1, %2, ... %9, respectively, where found. For example:

```
RUN  cl hello.c"
RUN "%1 %2 %3 %4 %5 %6 %7 %8 %9"
```

The second example would be embedded in a script called TEST.SCR. The syntax from the DOS command line might look like this:

```
C:\UNDOC2\CHAP5>CMDSPY COMPILE TEST cl hello.c
```

Passing DOS statements directly to CMDSPY from the DOS command line while an INTRSPY script is running is not supported. It is necessary only when you want to investigate a program that spawns other programs. Both CMDSPY.EXE and CMDSPY.COM must be in your search path. Use CMDSPY.EXE if you want an entirely self-contained script, or if you want to use the DEBUG statement.

REPORT, STOP and RESTART Syntax

REPORT, STOP, and RESTART take no parameters.

DEBUG Syntax

If an associated interrupt occurs during a RUN statement, the DEBUG statement invokes a simple interactive debugger that allows access to some of CMDSPY's output capabilities from a command line. Debugger commands are as follows:

- R displays the registers as they were when the caller generated the interrupt but also reflects any modifications made using the M (Modify) command. It replicates the REGS output element type.
- D displays a segment:offset (called linear offset) memory reference. Displays an area of memory as a result of the DUMP command's output element, but without the parentheses.
- M modifies the memory area. Modifies the contents of a register to a new value, which may be any numeric literal.
- C cancels all register modifications and returns all register contents to their values at entry.
- N asks whether to accept the modifications you have made. N means the modifications either to be canceled or allowed to remain in effect.
- Enter key allows you to key in previous commands for editing. The command line is fully editable using the normal cursor keys. ESC clears the command line, which is permanently in Insert mode.

An INTRSPY script that invokes the debugger might look like this:

```
; OPEN.SCR
Intercept 21h
    Function 3dh
        on_entry
            debug "INT 21h Function 3Dh - Open File"
run "%1 %2 %3 %4 %5 %6 %7 %8 %9"
```

Note that the debugger is available only within a script that uses a RUN statement. As noted earlier, a RUN statement can contain either a string literal (for example, RUN "CL HELLO.C") or parameters specified on the DOS command line. In this example, you might then type the following at the DOS prompt:

```
C:\UNDOC2\CHAP5>cmdspy compile open cl hello.c
```

At the first call to INT 21h Function 3Dh, you would be in the debugger, as shown in Figure 5-7.

Figure 5-7: The INTRSPY Debugger

```
=================================== INTRSPY DEBUGGER ===================================
 AX   BX   CX   DX   BP   SI   DI   DS   ES   SS SP     CS IP      FLAGS
3D00 371E 0000 0437 3094 33F0 08E0 4173 4173 4173 308E 3C34-3B09  odItszaPc
>>d ds bx->byte,asciiz,64
C:\MSC\BIN\cl err
>>x
```

Note that at the debugger prompt, you can type in expressions similar to those enclosed in INTRSPY scripts. As noted earlier, the DEBUG statement only invokes the debugger when executed in a script with a RUN statement. Without RUN, DEBUG is a NOP.

Predefined Constants

The following constants are provided within the script language and the debugger:

- OS_MAJOR and OS_MINOR. The major and minor DOS version number obtained from INT 21h Function 30h (Get Version).
- LOL_SEG and LOL_OFS. The segment and offset portions of the DOS List of Lists (SysVars), obtained from INT 21h Function 52h (SysVars).
- SDA_SEG and SDA_OFS. The segment and offset portions of the address of the primary Swappable DOS Area, obtained from INT 21h Function 5D06h (Get Swappable DOS Area). This is useful in capturing the network redirector and for spawning processes such as the current PSP. For example,

```
intercept 21h
    function 50h
        on_entry
            if (bx != (sda_seg sda_ofs[10h]->word))
                output "PSP changed to" bx
```

Error Messages

CMDSPY Compilation Messages. CMDSPY generates explanatory compiler error and warning messages and indicates where a problem is. The following shows sample CMDSPY output when an error is encountered:

```
File: BAD.SCR
Line 2:     field1      (word, ptr, 3)
                         ***
Error, PTR format can only be used with DWORD fields
```

The first line shows that BADSCR was the DOS CMDSPY was scanning when it encountered the error. The next line shows that the error occurred on line 2. The file and the asterisks show the token that was in error. Last is the actual error message. The following shows one of the warning messages that do not stop compilation but that draw attention to something that may be important or that may affect the results that you expect:

```
File: DD_INTR.SCR
Line 3: intercept interrupt("A:")
                            ***
Warning: Same block device driver supports multiple drives
16 bytes of code generated for 'A:' driver interrupt script
```

In this example, the compiler was told that the same device driver handles requests for A: as presumably B: and C: as well. The results that you obtain will relate to unit only to A:, but not to other drives. This condition is not a fatal error, so compilation proceeds.

CMDSPY and INTRSPY in Operation Both CMDSPY and INTRSPY respond to a ? or /? command-line switch with a summary of their command-line options. In addition, they generate various unexpected error messages—many of which are purely informational, but some of which are errors. All of these behaviors will be worth keeping in mind as we look at some of the more interesting messages here.

One message you'll encounter frequently if you are watching INT 21h and use STOP or UNLOAD to terminate the script is

```
Cannot disable current INTRSPY Int 21h Handler.
It is handling the DOS Exec of CMDSPY.
Try again  amed afterv and it will disable successfully
```

When INTRSPY is active, INT 21h or INT 2Fh calls all those functions that are not the subject of the script's interest. These calls are passed along for the script to simply ignore. However, when the script has passed control to DOS to load and execute a program, and that program has completed, a function is called back through the INT 2Fh chain. Since CMDSPY itself is loaded by the DOS command interpreter issuing a function 4Bh INT 21h call, it cannot be unloaded until that function has returned. The handler sets a flag to prevent unloading and passes control to DOS so that subsequent INT 21h calls do not pass through it. If you attempt to unload CMDSPY with STOP or UNLOAD command is issued, the handler can be called. It responds with

```
Cannot disable current INTRSPY script.
Remove any subsequently loaded TSRs and try again
```

To see the message, compile the INT 9C.SCR file included on the accompanying disk and then invoke the PHANTOM program presented in Chapter 8. Then load PHANTOM. Unload attempts to succeed. Then type CMDSPY /STOP. The "cannot disable" message is generated because PHANTOM's INT 2Fh handler was installed after the INT 21h SCR handler was installed. CMDSPY's handler's chain vector points at our handler. But it does not pass control to PHANTOM's handler. Instead, PHANTOM's handler is called via the chain to remove the 2 bytes of code that CMDSPY's handler patches PHANTOM's handler to keep up its responsibility to prior INT 2Fh handlers. Once CMDSPY's vector, an address in our resident code, and will pass control to it, the DOS INT 21h SCR handler will execute and load the contents of memory at the address that PHANTOM claims to would be indeterminate.

Only by [illegible] can CMDSPY be assured of stopping PHANTOM. Use to unload it. Actions generated by the unloaded DOS INT 21h handler will then safely unload it from memory. Similar actions would be required to unload other TSRs that have installed after INTRSPY.

INTRSPY Utility Scripts

Let's now take a look at several more applications for using the INTRSPY language.

UNDOC

The UNDOC.SCR script for INTRSPY quickly shows where undocumented DOS calls a program makes. Some of the scripts presented in Chapter 1 but there we were interested only in the Initial [illegible] INTRSPY itself. Here we use it to examine two pieces of system software: the Microsoft CD-ROM Extensions MSCDEX and the NetWare shell NET3. A step-by-step account is given in Figure 5-8. The script's shows some CMDSPY output which we have until now been omitting as irrelevant.

Figure 5-8. INTRSPY UNDOC.SCR Watching MSCDEX and NET3

```
C:\BIN> intrspy                                    (1)
8192 bytes allocated for code and results.
```

```
INTRSPY v2.00 loaded
C:\BIN> cmdspy compile undoc                          (2)
715 bytes of code generated for Int 21h script
65425 bytes of code generated for Int 20h script
65425 bytes of code generated for Int 27h script
27 bytes of code generated for Int 2Eh script
UNDOC.SCR compiled successfully.
2928 bytes of space used for code and overhead
5264 bytes of results space available.
Handler for Int 21h started.
Handler for Int 20h started.
Handler for Int 27h started.
Handler for Int 2Eh started.
C:\BIN>mscdex /d:xrw1001 /l g                         (3)
MSCDEX Version 2.20
Copyright (C) Microsoft Corp  1986, 1987, 1988, 1989, 1990  All rights reserved
    Drive G: = Driver XRW1001 unit 0
C:\BIN> cmdspy report                                 (4)
Handler for Int 21h stopped
Handler for Int 20h stopped
Handler for Int 27h stopped.
Handler for Int 2Eh stopped.
UNDOC.SCR compiled successfully.

---------- ----      --- Start of Report ---------- ----------

------------------ ---  -                             (5)
C:\BIN\MSCDEX.EXE
2152: Get List of Lists  011C 0026
--------- TSR    -                                    (6)
C:\BIN\CMDSPY.EXE
2152: Get List of Lists: 011C 0026

------------  -       -    End of Report ----------------------

All counters zero

148 bytes of results reported
Intrspy returned successful status
C:\BIN> cmdspy flush                                  (7)
INTRSPY Buffer flushed
C:\BIN> net5                                          (8)
    .
    .
C:\BIN> cmdspy report                                 (9)
Handler for Int 21h stopped
Handler for Int 20h stopped
Handler for Int 27h stopped.
Handler for Int 2Eh stopped.
UNDOC.SCR compiled successfully.
----------------------   Start of Report ----------------------

--------------
C:\NOVELL\NET5.COM
2134  InDOS flag  0116:0321
2134  InDOS flag  0116:0321
2152  Get List of Lists  0116:0026
2150  Set PSP  0486
2150  Set PSP  0B58
~~~~~~~~~ TSR -  ~~~~~~~~
2151  Get PSP  0486
2152  Get List of Lists  0116:0026
```

```
C:\BIN\CMDSPY.EXE
2152: Get List of Lists: 0116:0026
----- ---------- End of Report ----------
All counters zero.
148 bytes of results reported.
Intrspy returned successful status.
```

At 1, INTRSPY loads using the default allocations for interrupt handling code and results space. At 2, UNDOC.SCR is compiled. The version of UNDOC.SCR shown in Listing 5-7 includes some functions, such as INT 21h AH=34h and AH=50h, which were documented for DOS 5.0.

Listing 5-7: UNDOC.SCR (Includes Some Documented Calls)

```
;; UNDOC.SCR
intercept 21h
    function 1Fh on_exit output "21=1F  Get Default DPB  " DS ":" BX
    function 32h on_entry output "21=32  Get DPB  " DL
    function 34h on_exit output  21=34  InDOS flag  " ES ":" BX
    function 50h on_entry output "21=50  Set PSP    BX
    function 51h on_exit output  21=51  Get PSP    BX
    function 52h on_exit output  21=52  Get List of Lists  " ES ":" BX
    function 53h on_exit output  21=53  Translate DPB"
    function 5Dh subfunction 06h
        on_exit output  21=5D06  Get DOSSWAP    DS:SI
    function 60h
        on_entry output  21=60  Canon File:   (DS:SI->byte,asciiz,64)
        on_exit same line   ==>   (ES:DI->byte,asciiz,64)
    function 25h
        on_entry
            if (al    28h) output  SetVect INT 28h  KBD busy loop"

;;
;; Use the next functions and ints 20h and 27h to show which
;; program made the undoc DOS call, and to show termination
;;
    function 4Bh
        subfunction 00h
            on_entry
                output (DS:DX >byte,asciiz,64)
        subfunction 01h
            on_entry
                output  21=4B01  EXEC debug    (DS:DX->byte,asciiz,64)
    function 4Ch on_entry output "-------------------------
    function 31h on_entry output "--------- TSR ---------
intercept 20h on_entry output       ------------------"
intercept 27h on_entry output  -  ------ TSR ----------"
intercept 2Eh on_entry output  2E  Execute command"
```

At 3, MSCDEX runs. At 4, a screen report of the results to this point is generated. So that it is possible to destroy resources which MSCDEX allocates, generated by which program in the event that we want to terminate MSCDEX for a while or in the event that one program spawns others, the script monitors the DOS EXEC and termination functions and interrupts. The use of hyphens at 5, at the end of the run of CMDSPY from 2 that loaded the script. The line following it shows that MSCDEX has started. At 6, MSCDEX has terminated but stayed resident. In the next line we see the invocation of CMDSPY to respond to step 4. At 7, the result space is cleared; this action isn't really necessary, but it ensures that the next report is limited to what happened to NET.EXE without reiterating the MSCDEX results. At 8, NET.EXE runs, and at 9, the results of its loading are reported.

In this experiment, we see that MSCDEX calls INT 21h function 52h at load time, and that NET.EXE, in addition to function 52h, also calls functions 34h and 50h. The reasons these programs

make these particular DOS calls should be clear to you from other chapters. The DOS List of Lists retrieved with Function 52h contains a pointer to the DOS Current Directory Structure. MSCDEX alters the CDS. Functions 34h and 50h are both important for TSRs like NE1S.

LSTOFLST

In Chapter 2, we went through a fairly laborious process using C to display SysVars, the DOS List of Lists. It is simpler to do this with INTRSPY, as seen in Listing 5-8 (LSTOFLST.SCR).

Listing 5-8. LSTOFLST.SCR Displays SysVars

```
; LSTOFLST.SCR
; INTRSPY script to examine DOS List Of Lists (INT 21h Function 52h)
structure list_20 fields            ; DOS 2.x
    share_retry_count (word, dec)
    retry_delay (word, dec)
    curr_disk_buff  (dword, ptr)
    unread_con (word, dec)
    mcb (word)
    dpb (dword, ptr)
    file_tbl (dword, ptr)
    clock (dword, ptr)
    con (dword, ptr)
    num_drives (byte, dec)
    max_bytes (word, dec)
    first_disk_buff (dword, ptr)
    nul (byte,dump,18)
structure list_30 fields            ; DOS 3.0
    share_retry_count (word, dec)
    retry_delay (word, dec)
    curr_disk_buff (dword, ptr)
    unread_con (word, dec)
    mcb (word)
    dpb (dword, ptr)
    file_tbl (dword, ptr)
    clock (dword, ptr)
    con (dword, ptr)
    num_blk_dev (byte, dec)
    max_bytes (word, dec)
    first_disk_buff (dword, ptr)
    curr_dir (dword, ptr)
    lastdrive (byte, dec)
    string_area (dword, ptr)
    size_string_area (word, dec)
    fcb_tbl (dword, ptr)
    fcb_y (word, dec)
    nul (byte,dump,18)
structure list_31 fields            ; DOS 3.1+
    share_retry_count (word, dec)
    retry_delay (word, dec)
    curr_disk_buff (dword, ptr)
    unread_con (word, dec
    mcb (word)
    dpb (dword, ptr)
    file_tbl (dword, ptr)
    clock (dword, ptr)
    con (dword, ptr)
    max_bytes (word, dec)
    disk_buff (dword, ptr)
    curr_dir (dword, ptr)
    fcb (dword, ptr)
    num_prot_fcb (word, dec)
    num_blk_dev (byte, dec)
```

```
    lastdrive (byte, dec)
    nul (byte,dump,18)
    num_join (word, dec)

intercept 21h
    on_exit
        function 52h
            output "DOS Version is " (OS_MAJOR, dec) "." OS_MINOR
            if (OS_MAJOR == 2)
                output (es:bx[-12]->list_20)
            if (OS_MAJOR == 3) and (OS_MINOR == 0)
                output (es:bx[-12]->list_30)
            if (OS_MAJOR == 3) and (OS_MINOR != 0)
                output (es:bx[-12]->list_31)
                output ""
                output "CON device header"
                    (es:bx[-12]->list_31.con->byte,dump,18)
                output ""
                output "CLOCK device header"
                    (es:bx[-12]->list_31.clock->byte,dump,18)
            if (OS_MAJOR > 3)
                output (es:bx[-12]->list_31)
                output ""
                output "CON device header"
                    (es:bx[-12]->list_31.con->byte,dump,18)
                output ""
                output "CLOCK device header"
                    (es:bx[-12]->list_31.clock->byte,dump,18)
        function 52h
            output

;; Issue an Int 21h/AH=52h
generate 21h
    on entry
        ah = 52h

report
```

Note that we can display an entire structure with one OUTPUT statement. CMDSPY takes care of how all the output is according to the format options specified in the structure itself. When you are displaying just one structure with a single OUTPUT statement, CMDSPY also takes care of displaying the field names. For example, sample output from INTCMD.SCR is shown in Figure 5-9. This output was produced under DOS 5.0. The structure is called LIST_31 because the fields we are examining here haven't changed since DOS 3.1.

Figure 5-9: INTRSPY Displays SysVars (the List of Lists)

```
DOS Version is 5.00

LIST_31.SHARE_RETRY_COUNT      : 3
LIST_31.RETRY_DELAY              1
LIST_31.CURR_DISK_BUFF           FFFF:A078
LIST_31.UNREAD_CON               0
LIST_31.MCB                      0253
LIST_31.DPB                      0176 1362
LIST_31.FILE_TBL                 0176 0CCC
LIST_31.CLOCK                  : 0070 0059
LIST_31.CON                      0070 0023
LIST_31.MAX_BYTES                512
LIST_31.DISK_BUFF              : 0176:0060
LIST_31.CURR_DIR               : 0381 0000
LIST_31.FCB                    : 034F 0000
LIST_31.NUM_PROT_FCB           : 0
LIST_31.NUM_BLK_DEV            : 3
LIST_31.LASTDRIVE              : 12
```

```
LIST_31.NUL
0000 | 00 00 9D 02 04 80 C6 0D CC 00 4E 55 4C 20 20 20 |    .      NUL   |
0010 | 20 20                                           |                  |
LIST_31.NUM_JOIN              : 0

CON device header
0000 | 35 00 70 00 13 80 F5 06 00 07 43 4F 4E 20 20 20 |5.p    .   CON    |
0010 | 20 20                                           |                  |

CLOCK device header
0000 | 6B 00 70 00 08 80 F5 06 39 07 43 4C 4F 43 4B 24 |k p     9.CLOCK$|
0010 | 20 20                                           |                  |
```

The GENSERVE command now for this version allows you to generate an interrupt so that you can trigger a record of the contents of SysVars without waiting for some program to first call INT 21h AH=52h for you. Note also how a hex dump can be produced with the DUMP output statement for example *DUMP ES:BX 12 /* dump 12 bytes of list into dump.18 */* treats ES:BX+12 as a pointer to a DPB. DPB structure treats the CLOCK field within that structure as the far address of one or more bytes and then hex dumps 18 bytes at that address.

Log Your Machine's Activity

Out of the NDOS.SCR contains a handful of reads made from an application for INTRSPY. Using this section of NDOS.SCR as a starting point, you can write a script, EXEC.SCR, that will maintain a log of all the programs run on a computer, together with their command line arguments, starting times, and completion codes. This script is shown in Listing 5-9.

Listing 5-9: EXEC.SCR Logs Program Activity

```
; EXEC.SCR
structure param_block fields
    env_seg (word,hex)
    args (dword,ptr)

intercept 21h
    function 0ah
        on_exit output (ds:dx[1]->byte,string,60)
    function 4bh
        on_entry
            output
                (0.046Ch->dword,dec) "    "                    ; time
                (ds.dx >byte,asciiz,64)                        , executable
                (es bx >param_block args >byte,string,32) ; cmdline args
        on_exit
            if (cf.ag == 1) sameline " [FAIL " ax"]"
    function 00h 4ch
        on_entry sameline " [RET " al "]"
    function 31h
        on_entry sameline " [TSR " al "]"

intercept 20h
    on_entry sameline " [RET20 " al "]"

intercept 27h
    on_entry sameline " [TSR27 " al "]"
```

This script reports on all calls to the DOS EXEC function and on all calls to the surprisingly large number of DOS functions and interrupts that handle program termination. INT 21h function 0Ah (Buffered Keyboard Input) is intercepted so that the actual command line typed by a user can also be inspected. It might seem that function 0Ah can rarely be used by programs. (But even COMMAND.COM uses EXEC.SCR.) also displays the ROM BIOS timer tick count and clock display to show how much time was spent in each program. Here is sample output from EXEC.SCR after compiling HELLO.C with Microsoft C 6.0:

```
cl hello c
 534139   C:\MSC\BIN\CL EXE hello c
 534150   C:\MSC\BIN\c1 exe [RET 00]
 534194   C:\MSC\BIN\c2.exe [RET 00]
 534263   C:\MSC\BIN\c3 exe [RET 00]
 534312   C:\BIN\link exe wd \\c:\tmp\004951lk\  [RET 00] [RET 00]
cmdspy report
 536537   C:\UNDOC\MAXEY\CMDSPY EXE report [RET 00]
```

to the nearest 55 milliseconds spent on a program subtract its tick count for example, 534 2e3 from the tick count at the start of the next program then divide the result by 18 2 the number of timer ticks per second)

EXEC SCR provides a simple batch script interface to INTRSPY Notice that all the termination functions use SAMELINE so that the program termination status will be printed on the same line as the invocation Here's a batch file that spawns a program as CL EXE logs the activity and then displays the report which appears on the appropriate line A future version of INTRSPY should auto indent in which case the EXEC SCR code would have the SAMELINEs replaced with OUTPUT INTRSPY should also accept input stack so that results could be sent back to the EXEC SCR accomplishes a task a detection for which others have no doubt spent days writing complete programs The EXEC SCR script took only a few minutes to code test and refine

Monitoring Disk I/O

Interrupt spy can be a tremendous debugging tool after you've used it imagine how long it would take to write from scratch

The idea behind DISK SCR is to see DOS level (DOS file system calls made as specific processes as well as to log the related BIOS disk activity generated by such calls This script does the following command to run a specific program that you want to monitor This helps you watch as an example FORMAT COM without inadvertently also watching COMMAND COM

Listing 5 10 DISK.SCR Watches Disk Related DOS and BIOS Calls

```
;   DISK SCR
;   This script relates DOS disk calls to the hard disk
;   BIOS calls involved
;
; DOS 4+/Compaq DOS 3.31+ >32M partition
structure big fields
    sector (dword,hex)
    num (word,hex)
    addr (dword,ptr)

intercept 21h
    function 32h
        on_entry output "2132: Get DPB drive " dl
;    function 40h
;        hook WRITE (just to see messages (e g , from FORMAT)
;        on entry if (bx    1)    , stdout
;            output (ds dx->byte,asciiz,cx)
    function 44h
        subfunction 09h
            on_entry output  "4409  IOCTL drive " bl   Remote? "
        subfunction 0dh
            on_entry output "440D: IOCTL drive " bl
                if (cl    40h) sameline   [40  Set Device Parameters]"
                 (cl == 42h) sameline   [42  Format and Verify Track]"
                if (cl    60h) sameline " [60: Get Device Parameters]"
        subfunction 0fh
            on_entry output  "440F  IOCTL Set Logical Drive " bl
```

```
        on_exit if (cflag == 0) sameline " ==> " al
    function 60h
        on_entry output  2160: fanon " (ds:si->byte,asciiz,32) " ==>
        on_exit sameline (es:di->byte,asciiz,32)
intercept 25h
    on_entry
        output "25: Abs Disk Read drv " al ", at sectr "
        if (cx == 0FFFFh)
            sameline (ds:bx->big sector) ", "
                     (ds bx >big num) " sctrs"
        if (cx != 0FFFFh)
            sameline dx ",   cx   sctrs"
    on_exit if (cflag==1) sameline " [fail]"
intercept 26h
    on_entry
        output "26: Abs Disk Write drv " al ", at sectr "
        if (cx == 0FFFFh)
            sameline (ds bx->big sector) ", "
                     (ds bx >big num) " sctrs"
        if (cx != 0FFFFh)
            sameline dx ", " cx " sctrs"
    on_exit if (cflag==1) sameline " [fail]"
intercept 13h
    function 0 on_entry output  1300  Recalibrate drive " dl
    function 1 on_exit output "1301  Disk system status   al
    function 2
        on_entry
            output "1302: Read " al " sctrs, drv " dl ", head " dh
                ", sctr " cl ", trk " ch
        on_exit if (cflag==1)
            sameline " - FAILED (" ah ")"
    function 3
        on_entry
            output  1303  Write   al " sctrs  drv " dl  , head " dh
                ", sctr " cl ", trk " ch
        on_exit if (cflag==1)
            sameline "   FAILED (" ah ")
    function 4
        on_entry
            output "1304  Verify " al " sctrs: drv " dl ", head " dh
                ", sctr   cl  , trk " ch
        on_exit if (cflag==1)
            sameline " - FAILED (" ah ")"
    function 5
        on_entry
            output "1305: Format " al   sctrs. drv " dl ", head " dh
                ", sctr   cl  , trk   ch
        on_exit if (cflag==1)
            sameline   - FAILED (" ah ")"
    function 8
        on_entry
            output "1308: Get drive params for " dl
        on_exit
            if (cflag==1) sameline " - FAILED (" ah  )"
            if (cflag==0)
                output "Type " bl ", " dl " drvs, max head " dh
                    ", max sctr " cl ", max cyls " ch
    function 0ch
        on_entry output  130C- Seek to cyl " ch ", drv " dl ", head " dh
        on_exit if (cflag==1) sameline " - FAILED (" ah ")"
    function 0dh
        on_entry output "1300  Alternate reset drive " dl
        on_exit if (cflag==1) sameline "  FAILED (" ah ")
```

```
    function 10h
        on_entry output  1310  Test drive " dl
        on exit sameline " - status " ah
    function 15h
        on_entry output "1315: Get type drv " dl
        on exit
            sameline ";
            if (ah==0) sameline "No disk present : sctrs " cx dx
            if (ah==1) sameline "Floppy  Not changed - sctrs " cx dx
            if (ah==2) sameline "Floppy  changed  sctrs  cx dx
            if (ah==3) sameline "Fixed disk : sctrs " cx dx
    function 16h
        on entry output  1316  Get media change drv " dl ",
        on exit
            if (ah==0) sameline "Unchanged"
            if (ah==6) sameline "Changed
    function 17h
        on_entry
            output "1317, Set type drv " dl
            if (ah==0) sameline "no disk"
            if (al==1) sameline "reg disk in reg drv"
            if (al==2) sameline "reg disk in high dens. drv"
            if (al==3) sameline "high dens disk in high dens. drv"
            if (al==4) sameline "720k disk in 720k drv"
            if (al==5) sameline "720k disk in 1.44M drv"
            if (al==6) sameline "1.44M disk in 1.44M drv"
    function 18h
        on entry
            output  1318  Set media type drv  dl    sctrs/trk  cl
                , trks " ch "; "
        on_exit
            if (ah==0) sameline "OK"
            if (ah==1) sameline "Not available"
            if (ah==0ch) sameline "Not supported"
            if (ah==80h) sameline "No disk in drive"
run %1 %2 %3 %4"
report
```

Note that the script dumps the results to the screen. It is sometimes useful to see the output immediately and then to be able to review it in an editor. To capture the results to a file, sample run CALLSPY REPORT1 = FORMAT C: /U after the run has completed.

Figure 5-10 shows a small portion of the output from DISK SCR that results from formatting a double-density 5.25" diskette. You can see that there is also a small amount of output not generated by FORMAT.EXE. The first four lines of the CALLSPY.REPORT also show DOS loading FORMAT.COM from the hard disk (drive 80h).

Figure 5-10: INTRSPY DISK SCR Watches FORMAT B:

```
1302  Read 01 sctrs  drv 80, head 03, sctr 06, trk 71
1302  Read 01 sctrs: drv 80, head 01, sctr 1D, trk 00
1302  Read 40 sctrs  drv 80, head 03, sctr 06, trk 71
1302  Read 01 sctrs  drv 80, head 04, sctr 07, trk 71
21440D  IOCT  drive 02 [60  Get Device Parameters]
214409: IOCTL drive 02 Remote?
214409: IOCTL drive 02 Remote?
2160. Canon B.CON => B:/CON
21440D  IOCTL drive 02 [60  Get Device Parameters]
21440F: IOCTL Set Logical Drive 02 => 00
Insert new diskette for drive
B

and press ENTER when ready...
```

```
2144DD: IOCTL drive 02
2144DD: IOCTL drive 02
Checking existing disk format.

25: Abs Disk Read drv 01, at sectr 0000, FFFF sctrs
1302: Read 02 sctrs  drv 01, head 00, sctr 01, trk 00
Saving UNFORMAT information.

2132: Get DPB drive 02

 .. details omitted .

1316: Get media change drv 01- Unchanged
25: Abs Disk Read drv 01, at sectr
1302: Read 01 sctrs  drv 01, head 01, sctr 01, trk 00
25: Abs Disk Read drv 01, at sectr
1302: Read 02 sctrs  drv 01, head 00, sctr 08, trk 00
25: Abs Disk Read drv 01, at sectr

... details omitted

2144DD: IOCTL drive 02 [40  Set Device Parameters]
2144DD  IOCTL drive 02 [42  Format and Verify Track]
1318: Set media type drv 01  sctrs/trk 0F, trks 4F: OK
2144DD: IOCTL drive 02
1304. Verify 0F sctrs: drv 01, head 00, sctr 01, trk 00

  0
 percent completed.
2144DD  IOCTL drive 02
1304: Verify 0F sctrs- drv 01, head 01, sctr 01, trk 00

  1
 percent completed.
2144DD  IOCTL drive 02
1304: Verify 0F sctrs  drv 01, head 00, sctr 01, trk 01

 .. details omitted .

100
 percent completed.
Format complete

26: Abs Disk Write drv 01, at sectr 0000, FFFF sctrs
1303. Write 01 sctrs  drv 01, head 00, sctr 01, trk 00

  . details omitted .

2144DD. IOCTL drive 02 [40  Set Device Parameters]
2132  Get DPB drive 02
1302  Read 01 sctrs  drv 01, head 00, sctr 01, trk 00
1302: Read 01 sctrs  drv 01, head 00, sctr 02, trk 00
1302. Read 01 sctrs  drv 01, head 00, sctr 01, trk 00

  . details omitted
```

Whereas DISK SCR groups functions together by interrupt and function number, the output resulting from running the script together with the DOS FORMAT command is quite different. Here you see the testing of BIOS calls by DOS calls. In Figure 5-10 you can see how FORMAT displays the Hex FAT code. My XT-clone was able to show more information, 2144h, 2104h, and 2140h. It then calls DOS INT 21h Function 44h Subfunction 0Dh to format and verify a track. Subsequent calls BIOS INT 13h Functions 18h, 05h, and 04h to format and verify the sectors that make up the track. After the format itself is complete, as the above INTRSPY output shows, it creates the FAT and root directory on the newly formatted disk. FORMAT calls the DOS Absolute Disk Write interrupt, INT 26h. This interrupt in turn eventually calls the BIOS Write Sector Function, INT 13h Function 03h. In brief, DOS calls a device driver which in turn executes the BIOS; see Chapter 8.

DISK SCR handles INT 25h and INT 26h calls on systems with partitions larger than 32 megabytes. This function is performed even when you are formatting a floppy disk, because each hex

FORMAT uses the alternate form of INT 26h where CX holds the value FFFFh and DS:BX points to a structure that DISK SCR is called BIG. You can also see from this display that FORMAT uses two undocumented DOS calls: Resolve Path String to Canonical Path String (INT 21h Function 60h) and Get DPB (INT 21h Function 32h). Again, having INTRSPY means that you can do this kind of exploring without disassembling the code.

MEM

One last INTRSPY script worth examining is MEM.SCR (Listing 5-11), which in 24 lines of INTRSPY code can monitor all DOS memory allocation by intercepting INT 21h Functions 48h (Allocate), 49h (Release) and 4Ah (Resize). Again, Function 4Bh (EXEC) is monitored as well, so that you can see which program performed the memory operation. Chapter 7 presents a more comprehensive version of MEM.

Listing 5-11: MEM.SCR Watches DOS Memory Management Calls

```
; MEM.SCR
intercept 21h
    function 48h
        on_entry
            output "ALLOC " (bx, dec) " paras"
        on_exit
            if (cflag==1)
                sameline " FAIL (" (ax, dec) "), only " (bx, dec) " available"
            if (cflag==0)
                sameline " - seg " ax "h"
    function 49h
        on_entry output "FREE seg " ax "h"
        on_exit if (cflag==1) sameline " denied (" (ax, dec) "h)"
    function 4ah
        on_entry
            output "REALLOC seg " ax "h to " (bx, dec) " paras"
        on_exit
            if (cflag==1)
                sameline " FAIL (" (ax, dec) "), only " (bx, dec) " available"
    function 4bh
        on_entry output (ds:dx->byte,asciiz,64)
```

MEM can be used to track down memory allocation bugs, but it is also useful in a hands-on examination of the DOS memory allocation services discussed in Chapter 3 of this book. For example, you can see immediately that DOS programs typically are allocated all available memory:

```
E \UNDOCU\MAXEY\HELLO.EXE
ALLOC 65535 paras FAIL (8), only 37705 available
ALLOC 37705 paras - seg 161Bh
FREE seg 161Bh
```

Space does not allow me to show all the uses that even my limited imagination has found for INTRSPY.

Writing a Generic Interrupt Handler

Let's step back now and discuss some of the design issues behind INTRSPY. Some of this sounds like after-the-fact specification for INTRSPY because, in fact, it does come from the functional specification initially drawn up for INTRSPY.

In the early '90s, programmers would write a host of small, tailor-made programs to perform the kind of exploration we have been doing. In the past, I have written separate programs to monitor NetBIOS (INT 5Ch calls), DOS (INT 21h calls) and EMS (INT 67h calls). The cycle has been to write a simple TSR, debug it and eventually have something that could print or watch register val-

ues into or out of intercepted functions. In principle, that initial version cost a few weeks of coding and debugging effort. Subsequent versions that refined the list of functions being monitored or that added a new or increased capability came easier and more quickly, but they still required recompilation and debugging.

All monitoring programs are essentially the same, however, whether they monitor DOS, NetBIOS, EMS, or anything else. This suggests that it should be possible to write a generic monitoring program. By extension, this means writing a generic interrupt handler. The actual interrupts, functions, or subfunctions you wish to monitor would be parameters to the generic interrupt handler. To ensure that bending the tools doesn't detract from your investigations, the rapid modification of parameters, without the necessity of debugging, is a high priority. However, the need to specify a number of parameters that need to be specified each time, however, and the need for a broad range of capabilities suggest that a command line switch–based TSR is unlikely to be adequate. A script interpreting precompiled interrupt handling tool would be better.

Because DOS uses several different interrupt numbers and provides its services through functions and subfunctions within these interrupts, generally specified via AH and AL, and because you would want to be able to monitor these interrupts and their function calls selectively, INTRSPY must be capable of monitoring any subfunction of any function of any interrupt. It should therefore allow you to build some useful suggestive and exploitation applications not just to look at undocumented DOS calls but on a whole range of DOS-related and even DOS-related interrupt-based services. Logging DOS device usage would be simple. Recording DOS disk access to the underlying device drivers as well as BIOS interrupts watching EMS, XMS, or even DESQview or NetBIOS sessions. All these functions should be achievable simply by using different easily editable parameters. INTRSPY should be a platform for experimenting tools for PC software hackers.

The preliminary specification is beginning to form. The program should screen-oriented. This allows for transportable, executable, and general experiments and debugging tools. The program should intrude as little as possible. That is, it should make no DOS calls when it looks for interrupts and should consume little memory. Any interrupts that are generated by actions that are associated with interrupts that are intercepted, other than those that are suppressed, should be intercepted. Interactions, constants, noise, and collected information may make the sessions being monitored by CAMINSPY made undocumented DOS calls for example. These would show up in the report as UNDOCUMENTED. Thus it is perhaps more correct to say that it should be possible to monitor undocumented DOS calls as certain tools in the development of TSRs and system-level software. Such functions have been used in developing CAMINSPY and INTRSPY with as few undocumented DOS calls as possible. Other than its own code, INTRSPY generates no interrupts that access DOS services, memory, or

The program should provide snapshots of register contents, flags, and DOS and other structures in memory. The SYSVARSTRUCT structure was specified initially because of the DOS List of Lists structure and the associated DOS function 52h, Get List Of Lists, previously. As was initially known, however, once an initial capability of this type has been provided, bending it a little should make it useful in many, especially unexpected, ways. As was stated, the central requirement is to be able to look at memory contents session to session, on different selected actions of different functions of different interrupts, recording what should be easy and painless so that it does not impede the trial-and-error experimentation, or the debugging progress.

Access should be available before and after an interrupt is serviced. The program needs to be able to see and alter the parameters that the caller supplies as well as the structures, registers, and flags that the interrupt function returns.

A memory-resident transient portion should compose the scripts, hand them off to the resident portion, and decode the output. When we were first discussing the specification for INTRSPY, we had been using some of the other available interrupt monitoring software packages. It was not clear that any of them offered the flexibility we needed.

The options here were either a shell implementation or a TSR transient controller combination. In a shell implementation, programs under scrutiny would be run from within the system. Much like those of a debugger, a shell implementation's facilities would be available until the user quit the user interface. The problems with this approach include potentially much reduced memory availability for the program being studied and less flexibility to run commands and batch files as well as programs. Benefits include control over the environment and the ability to limit monitoring to a specific run of a particular program. Thus, INTRSPY includes this as an option with the RUN statement. We decided to go with the TSR transient controller combination. A relatively small TSR would perform the monitoring function, and a separate, less memory constrained program would perform script compilation, event formatting, and printing. It would handle all communications with the TSR. We saw this approach as preferable because the transient portion itself can be made to act as a shell.

This approach does have its disadvantages, however. Complexity is introduced through the decoupling of the compilation from the execution of the script. This is awkward only because, unlike normal compilation and execution cycles, script source is needed to be able to decode the results of the execution.

It is needed to process events results rather than write them to disk or pop up screens. This removes the necessity to place lots of I/O within the generic interrupt service routine (ISR) code. File I/O by its very nature generates interrupts, changes the state of the operating system by a little or a lot, and leads to coding complexity when implemented properly in ISRs, as is shown in Chapter 9.

The Problem with Intel's INT

Now that we have explained how to use INTRSPY and discussed some of the thinking behind it, we need to discuss briefly some problems with the Intel INT instruction. These problems stand in the way of writing a truly generic interrupt handler. The INT instruction is the source of a great deal of the flexibility in the PC architecture because the ability to get and set interrupt vectors means that system services, including DOS itself, are entirely extensible, replaceable, and monitorable. Yet, given its importance, the INT instruction is remarkably inflexible in two key ways:

- A program's interrupt handler does not know which interrupt number invoked it.
- The INT instruction itself expects an immediate operand: you cannot write MOV AX, 21h and then INT AX; you must write INT 21h.

The first problem raises the question: How will the program trap a variable number of user specifiable interrupts? There are at least three possibilities here.

The first possibility is to use a generic interrupt service routine for all interrupts the user specifies. When the ISR is invoked, it can use the return address on the stack to find out what INT instruction issued the interrupt.

This would indeed be an elegant, economical solution. Unfortunately, it is an unreliable strategy because many high-level language compilers and the important Simulate Int and Exec Int functions in Windows Enhanced mode compile interrupts into PUSHF and far CALL instruction sequences, rather than actual INT. Others push the address of the handler on the stack and RETF to it. In order to cover the different ways to simulate an INT instruction, a generic ISR would need a small disassembler.

One reason for all these different ways of performing what should simply be an INT is in fact the second problem: that the INT instruction itself can't be parameterized. Thus, different compiler vendors implement functions such as DOSKey differently.

The other stopping factor in the use of a possible implementation is that it relies on the caller's stack being large enough for an interrupt processing. Bear in mind that the program is going to have to be able to handle DOS internal functions, such as for which DOS will have switched to its own small stack of less than 400 bytes. For exact sizes, see the appendix entry for INT 21h Function 5D06h.

A second possibility involves creating 256 small stubs. Only those interrupts the user specifies would be redirected to the appropriate stubs. When invoked, a stub would record its interrupt number, save away the caller's stack, switch to the program's internal stack, then call the generic ISR. This is a better solution, but it will use several kilobytes of memory.

There are variations of these, but none were appealing, and I decided to go with what I thought was at least a more interesting solution—that is, to allocate a custom ISR object on the heap for each interrupt to be monitored. I called it an object because it was a structure containing machine code to perform stack switching, registers for saving state, and the specific compiled code associated with the interrupt processing. INTRSPY contained a skeleton ISR that was copied onto the heap and touched up with some run-time-dependent addresses. The interrupt processing was then actually performed by procedures called from the ISR machine code on the heap.

Will the program have to patch up the native data structure offsets at run time because I'm allocating on the heap, and therefore cannot expect every ISR structure to be paragraph aligned? No. Each ISR starts on a paragraph boundary, wasting up to 15 bytes per structure. This is not a significant overhead, allows the entry point as well as the data fields in the ISR structure to be at a constant offset. INTRSPY can thus be viewed as a program loader in which the programs are just small pieces of ISR code, and the handler space substitutes for DOS memory.

How should the interrupt processing instructions be stored? My first reaction was to think in terms of compilation into machine language. Instead, for the first version, I implemented a linked tree of small structures that describes the actions in the processing. The resident ISR processor in version 1.0 walked the linked structures (action records) stored for the interrupt that has been intercepted, processing the set of actions regardless of each. Each subfunction record was a linked list of subfunction records, each of which pointed to a "before" and "after" branch. These branches were in turn, linked lists of records that specified the conditionals and resulting actions to be performed before and after the interrupt is serviced.

Changed Implementation in INTRSPY 2.0

Version 2.0 was born out of experience with version 1.0, which is as it should be. A number of those early decisions have been overturned by some additional thoughts I have cast to the design changes.

For example, I now realize that I should probably have written a bit of machine code generation right from the start. Many of the powerful, newer script language features were expected as incremental efforts to implement the DOS-resident branching that I had taken from the database approach in INTRSPY 1.0. Indeed, many would simply not have been possible with that approach.

It also became clear that INTRSPY needed to be a little more clever in memory. Interrupt handlers generated and managed by CMDSPY. Most of the conversation between CMDSPY and INTRSPY was unnecessary. INTRSPY did not need a hand to be fostered. CMDSPY could treat INTRSPY as a block of memory that it could allocate. This approach produced a dramatic drop in the size of the resident, that is, ignoring the smaller result space allocation. INTRSPY memory footprint from 20K in 1.0 to less than 7K in 2.0.

Note that in 2.0 there is no need to know the undocumented interface between INTRSPY and CMDSPY. Anyone could write their own CMDSPY replacements. This was documented in Ralf Brown and Jim Kyle's *PC Interrupts*, and that we had also documented stuff in *Undocumented DOS*, but now most of this goes away. The interface in 2.0 is simple.

Implementation

Let us take a look at the structure of INTRSPY and its transient controller CMDSPY. The system functions as follows:

- INTRSPY is loaded and reserves some memory for holding intercept code and results data.

- COMDSPY compiles the specified script file on the basis of STRUCTURE and INTERCEPT constructs that implements the language as specified in the earlier *INTRSPY Version User Guide*. COMDSPY installs the compiled INTERCEPT code in the memory held by INTRSPY.

When a script has been compiled, COMDSPY stores the name of the input file that has just been processed, the directory that was current when it was processed, and any command line arguments that were passed to the script within INTRSPY's data segment for later retrieval. Finally, COMDSPY enables the interceptor handlers that have been installed. Doing so ensures that all handlers are plugged into the addresses that they are to intercept, which is done in the INTRSPY dispatch table.

Next, the command line arguments are parsed, and INTRSPY breaks up the results in memory. When a script has been compiled, COMDSPY disables the installed handlers by disengaging them from the addresses that they are to intercept.

COMDSPY then executes the script's directives. INTRSPY's commands. Although the script language supports a wide variety of control structures, it compiles them into offsets, lengths, and relative branches. Consequently, the only structure that is executed by INTRSPY. COMDSPY must recompile the script. For example, if the script's initial COMDSPY must make sure that the drive and directory that were current when the script was first compiled are the same as those that were specified on the command line. If they are not, COMDSPY changes the drive and directory to the arguments it was passed the first time. It is also COMDSPY's job to process the IF statement and other control structures during script compilation.

If a syntax error is encountered, COMDSPY makes its best effort at formatting and printing helpful information about the error and the structure of the script.

Pitfalls I Fell In

To wrap up this brief explanation of the INTRSPY implementation, let's look at some of the sticky issues. DOS jams in the spokes of a protected DOS. The first concerns a class of DOS functions that [illegible] of control. These are the process termination functions. What they have in common is that they do not return.

[illegible] what one wants in a terminate-and-stay-resident program is that it plugged on into the right while developing the code. INTRSPY. Any such functions, when executed, INTRSPY would just look up the interrupt vector to which it had [illegible] to. It would save that address in the INTRSPY data segment. Later, when DOS would [illegible] as when a program invoked the function 4Ch to terminate, INTRSPY would jump to the address that it had saved. Unfortunately, this [illegible] was being executed and its contents were [illegible]. Consequently, the system would [illegible] or IP values were corrupted. INTRSPY was modified to [illegible] DOS did not exit but deepened it and [illegible] shipping keyboard. Specifically, those which a termination function is called, DOS [illegible] any function or stack address stack while still in the process. [illegible] DOS stack. I had an opportunity to do something post-process.

The situation [illegible] Ctrl-Break and Critical Errors. When a DOS function [illegible] DOS breaks processing. In all cases it aborts the current [illegible] state of the system to the way it was prior to the DOS function's [illegible]. In the case of an Abort, replaces the original [illegible]. All [illegible] request. In that case, the INTRSPY interceptor [illegible] from the task that is currently intercepting, and its function stack is [illegible]. The solution for INTRSPY is to intercept INT 23h Ctrl-C and 24h Critical Error and record state [illegible] DOS next [illegible] intercepted if the application handler requests termination, it restores the [illegible] stack pointer until the previous EXEC or start of stack, whichever comes first.

Int 25h and 26h (the Absolute Sector Read/Write interrupts) must also be specially coded. Even though they are accessed through the interrupt mechanism, they are implemented as far called routines. This means that the flags that were pushed onto the stack by the Int 25h instruction are still on the stack, and that SP is not as it was before the instruction was issued. Therefore the stack must be adjusted by the caller.

Another DOS specific complication that we saw when reviewing CMDSPY messages involves the attempt to terminate (Int 21h Function 4Ch) a caller. As we saw, CMDSPY itself is running as part of a DOS EXEC function 4B0h call. If we were to unhook the ISR handling it as an Int 21h interrupt. Restoring the vector and potentially replacing it with the ISR's handler from would be disastrous since the DOS EXEC function would return to an address that had been long since scaled.

The key thing to remember here is that all this complication is encapsulated within the generic interrupt handler. INTRSPY. You can use the INTRSPY scripts happily without agonizing over the usual complications of interrupt handling, because INTRSPY attends to these details. This is a key benefit to using a high-level event-driven scripting language.

Because INTRSPY is becoming a commercial product, source code is not provided. If you are interested in getting a general overview of how an interrupt monitoring program works, you might want to look at Bob Flanders and Michael Hohmann, "Collecting Program Statistics with INTCAP," in *PC Magazine C Tools Sourcebook*, Ziff-Davis Press, 1993.

The Future of INTRSPY

INTRSPY is now at version 2.0 and is very robust and widely used debugging tool. Pressure for additional features and support has been growing, and although 2.0 is a considerable advance over 1.0, a still more significant upgrade is already planned for the first commercial release of INTRSPY version 3.0. A partial list of the candidate new features for that release includes:

- A full-fledged scripting language (more or less) incorporating support for named variables, math, and a powerful set of built-in functions.
- An interface to other languages, so that compiled code can call script procedures.
- Second-by-second statistics for real-time monitoring of events.
- Additional communications options, including VMS mail and transmission via serial or network connection to a second PC.
- Enhanced report and screen formatting capabilities.
- Full documentation.

For more information, please contact us through my CompuServe address: 70401,3457.

CHAPTER 6

Disassembling DOS

by Andrew Schulman

The previous chapter showed that it's possible to discover a lot about a program without resorting to what is often called reverse engineering. Simply by examining a program's external behavior, tools such as INTRSPY.EXE are able to tell, for example, that Windows uses the undocumented DOS Get SysVars function 5200h, and that Microsoft's Quicken makes the weird Set INT 0 and Set INT 1 calls that were discussed in Chapter 4.

But such external examination of a program's behavior can take us only so far. INTRSPY can't tell us how Windows uses Get SysVars data, which words it uses in the SysVars data structure, nor can INTRSPY tell us why Quicken passes the illegal value 0 to the DOS Set INT vector function. To figure out why a program behaves in a certain way, you need to actually get inside the program. This requires disassembly.

Disassembly is sometimes important to understand what goes on inside MS-DOS itself. What does DOS do after it has finished processing the Get SysVars function? How does DOS carry out an INT 21h AH=2Fh DAT request? How does DOS's Int 2Eh Command Shell work? Windows 3.0 answers questions like these by looking at the DOS code. Though Microsoft does provide the DOS OEM Adaptation Kit (OAK), that we discuss later in this chapter, source code for MS-DOS is not available. For more information about the DOS source code, understanding DOS requires disassembling it.

The goal of this chapter is to explain understanding DOS internals that is not otherwise available. For example, we'll show a program that makes an INT 21h DOS call. Chapter 7 briefly presented a disassembly of two DOS functions, INT 21h AH=0Eh Set Default Drive and INT 21h AH=19h Get Default Drive. Chapter 8 and INT 21h AH=30h Get DOS Version Number. But how does DOS know to execute these functions in the first place? We'll present a complete, if simple, DOS device driver to reveal the key part of MS-DOS: the INT 21h handler. Our device driver displays information about each function request DOS receives, and then passes control to the real DOS handler. Each call to INT 21h function 0Eh Select Default Drive, for example, is seen by the code that handles each function call. INT 21h function 0Eh Select Default Drive is also seen by the code that handles particular DOS functions, such as function 19h Get Default Drive. Finally, we'll see how the command processor code, such as the DOS shell's INT 2Eh handler, Novell NetWare's SHELL.COM, see Chapter 4

Disassembling DOS starts with IBMBIO.COM and IBMDOS.COM (or IO.SYS and MSDOS.SYS, as they're named by Microsoft). Both files are part of the DOS kernel. While there are many ways to examine the code in these files, this chapter instead examines the INT 2Fh multiplex interface, using Microsoft's own DEBUG.EXE to step through hundreds of kilobytes of MS-DOS.

Part of the reason for using DEBUG rather than a more sophisticated debugger or disassembler tool is to underline the point that Microsoft itself provides the means for reverse engineering DOS.

Since programmers frequently have questions about the legalities of disassembly, this chapter also [illegible] discusses the law surrounding reverse engineering and trade secrets.

Obviously there is more to DOS than just IO.SYS and MSDOS.SYS. There are also external programs such as COMMAND.COM, MSCDEX.EXE, and PRINT.COM, which is probably the most heavily disassembled DOS utility and the one on which many TSR writers first figured out their craft.

What you want your disassembled DOS to depend of course on what interests you. The examination of the INT 21h dispatcher code in this chapter may provide all you ever wanted to know about how DOS [illegible] is accessed. On the other hand, if you encounter a problem, you must know exactly what is going on inside MS-DOS and you have no money to pay for this information, you may want to buy Ray Duncan's *DOS Object Adaptation Kit*, which provides assembly language and C source code [illegible] parts of DOS, as well as OBJ files with full symbolic information for those parts where direct source code is not provided. We'll take a quick look at the OAK contents later on.

What is MS-DOS?

MS-DOS is a lot like pornography. Everyone knows what it is when they see it, but almost no one can define it.

Is it that MS-DOS is *not* the C:> prompt? While that infamous user interface seems practically synonymous with MS-DOS, it is not actually a necessary part of DOS. The C:> prompt is provided by COMMAND.COM, which, as Chapter 10 explains in more detail, anyone can easily replace. As Richard Stallman's famous statement in CONFIG.SYS—"COMMAND.COM is just a shell around the DOS kernel. Other shells such as 4DOS or the MKS Korn shell are widely available. Get rid of COMMAND.COM, and you still have MS-DOS."

From a programmer's perspective, MS-DOS seems like a collection of INT 21h functions. But this is not entirely correct either. While the INT 2Ah functions are the most important service provided by DOS, IO.SYS and INT 21h are not synonymous. Several application wrappers in Chapter 2 of listings 2-20 and 2-21 [illegible] show how easy it is for a normal program to fiddle with INT 21h calls before they get to DOS, and just because a piece of code handles INT 21h doesn't necessarily make it part of DOS.

So if DOS is not necessarily the C:> prompt or the INT 21h interface, what then is it? And where is it?

Ah, now you're getting to the point! It's easier to answer, except to note that DOS is in many ways what textbooks on operating systems are all about. DOS provides a small, bare minimum of services on top of which other, more sophisticated software can be built. A chunk of DOS is a software motherboard into which [illegible] can plug various extensions. These extensions are usually from Microsoft but [illegible] key third-party vendors such as Novell, Quarterdeck, Quarterdeck, Qualitas, Symantec, Central Point, and Phar Lap. DOS is the arena in which all these companies' products must both compete and work together.

Well, that was vague enough!

Nevertheless, the answer, or part of it, is easy to answer. MS-DOS consists of two files, IO.SYS and MSDOS.SYS. In both IBM PC-DOS and Novell DR-DOS, these files are called IBMBIO.COM and IBMDOS.COM. Despite the .SYS extension, these are not device drivers but binary images. In MS-DOS 6.0, there is a third file, DBLSPACE.BIN, which Microsoft generally considers a full-fledged third member of the DOS kernel. The SYS and FORMAT /S commands in DOS 6.0 copy DBLSPACE.BIN over to a floppy disk as well as IO.SYS and MSDOS.SYS. Take these two or three files, add a bare-bones DOS. Of course, you'll also need a shell such as COMMAND.COM in order to get much work done.

Among other things, MSDOS.SYS contains the DOS dispatch function, which is DOS's handler for INT 21h calls. There are other DOS functions such as INT 25h, 26h, and 24h, that MSDOS.SYS and IO.SYS handle as well.

IO.SYS consists of two parts: a loader (MSLOAD.COM) and BIOS support (MSBIO.BIN). Microsoft creates IO.SYS by concatenating these two files:

```
copy /b msload.com+msbio.bin io.sys
```

IO.SYS is *not* "the BIOS" as Undocumented DOS programming frequently claims, but it provides the DOS *interface* to the BIOS. IO.SYS contains the standard device drivers such as CON, AUX, PRN, and COM1 (see Chapter 7). These device drivers are implemented using BIOS calls. For example, the CON driver built into IO.SYS (more precisely, MSBIO.BIN) makes INT 10h and INT 16h calls to the ROM BIOS video and keyboard routines.

The MSLOAD.COM part of IO.SYS contains a famous set of routines called SYSINIT, which is responsible for the system's bootstrap loading of DOS.

We won't discuss SYSINIT because it's already been covered elsewhere (see "How MS-DOS Is Loaded" in Chapter 2 of Dr. Dobb's *Extended MS-DOS Programming* and "The Components of MS-DOS" in Dr. Dobb's *MS-DOS 5: A Developer's Guide*). And practically every other book on DOS programming seems to repeat the same basic information on SYSINIT. Presumably this is because the bootstrap process of DOS is an interesting subject, but also because Microsoft already documents SYSINIT. The DOS 6 DDK *Device Driver Kit* provides a fairly original and concise description of DOS startup in two places (*MS-DOS Internals*, Chapters 1 "The System Configuration", 2 "The System Initialization", and 3 "The Startup Sequence"). For example, Chapter 1 is the first author to make the connection between SYSINIT and the List of Lists structure, whose actual name in the DOS source code is "sysinitvars".

So the DOS bootstrap process is well and well known. What hasn't been provided before, amazingly, is any description of how a DOS looks like after it's up and running. This primarily requires a description of DOS's INT 21h handler and the INT 21h dispatch table. Another undocumented feature when you make an INT 21h call to DOS. Scores of DOS programming books of course describe exactly what the different DOS functions do, how they work, how they're called, and how to use them. But knowledge of the DOS internals, how all these functions work and how they're implemented, is still very scarce. Discussion of DOS stack switching in Microsoft's *MS-DOS Encyclopedia* (pp. 353-354) describes for DOS 5 what is an extremely complex mechanism itself. Documentation is more important than programming examples: standard descriptions of how DOS boots up (or how SYSINIT moves segments around in memory).

One of our main concerns is to find out where parts of the boot sequence are NOT (anymore) in DOS 6.0 and up. There is no more DOSINIT.BIN (IO.SYS uses a compressed DBLSPACE.BIN). And DOS 7.0 (Chicago) in CONFIG.SYS contains the setting DOS=HIGH,UMB=ENHANCED. There is code in IO.SYS that loads DOSMEM.EXE, which is a big executable similar to WIN386.EXE.

Disassembling IO.SYS and MSDOS.SYS

The choice between describing SYSINIT or describing the INT 21h handler is an important one because the portion of DOS which one is interested in looking at largely determines how one goes about disassembling DOS.

To look at DOS internals, the first thing to acquire is the DOS DDK, which provides assembly language source code to IO.SYS, including the SYSINIT modules. Next you have to disassemble the actual IO.SYS and MSDOS.SYS files on disk. These files are hidden system files, which however can be easily unhidden:

```
C:\UNDOC\CHAP6>attrib -h -s \*.sys
```

IO.SYS is about 32K, and MSDOS.SYS is about 47K. Once unhidden, these two files can be disassembled easily with DEBUG's *u* (unassemble) command in the primitive DEBUG that comes with DOS. After running VERIFY.EXE, which displays MSDOS.SYS or IO.SYS type, DIR to find its size. Then DEBUG loads the file at address 100h, so add 100h to the file size, convert it to hex, and use that to yield the disassembly end range. For example, if MSDOS.SYS is 37,986 (92822h) bytes:

```
C:\UNDOC2\CHAP6>type msdos.scr
u 0100 9382
q

C:\UNDOC2\CHAP6>debug \msdos.sys < msdos.scr > msdos.lst
```

The resulting MSDOS.LST is about one megabyte in size if you use a disassembler such as Sourcer (which is over 800K). In some ways the output from such a straightforward disassembly of MSDOS.SYS looks quite useful. For example, you can quite plainly see DOS's INT 21h handler respecting the valid function number limit in AH. This is the DOS code coded whenever a program generates an INT 21h

```
6A76:0408 FA            CLI
6A76:0409 80FC6C        CMP AH,6C       ; is function > 6Ch?
6A76:040C 77D2          JA  03E0        ; yes: error
6A76:040E 80FC33        CMP AH,33
6A76:0411 7215          JB  0428
6A76:0413 74A2          JZ  03B8
6A76:0415 80FC64        CMP AH,64
;       etc
```

I know that MSDOS.SYS INT 21h handler is accessible. IO.SYS has its own INT 21h handler, but in the last few lines of the code fragment below you can see the INT 21h handler in MSDOS.SYS is the one that IO.SYS uses (pushed word address).

```
1C53:07B9 FB            STI
1C53:07BA 80FC11        CMP AH,11
1C53:07BD 750A          JNZ 07C9
;;; Go to 07BFh if an INT 2Fh call belonging to an external
    program such as a redirector, SHARE, or NLSFUNC, ends up
;;; in MsDOS.SYS.  This means the external program isn't loaded
1C53:07BF 0AC0          OR  AL,AL       ; is AL=0?
;       error handling
1C53:07C1 80FC10        CMP AH,10       ; INT 2Fh AH=10h? (SHARE)
1C53:07C4 74F1          JZ  07BF        ; got here, so SHARE not loaded
1C53:07C6 80FC14        CMP AH,14       ; INT 2Fh AH=14h? (NLSFUNC)
1C53:07C9 74EC          JZ  07BF        ; got here, so NLSFUNC not loaded
1C53:07CB 80FC12        CMP AH,12       ; INT 2Fh AH=12h?
1C53:07CE 7503          JNZ 07D3
1C53:07D0 E99701        JMP 0972        ; handle DOS internal functions
1C53:07D3 80FC16        CMP AH,16       ; INT 2Fh AH=16h? (Windows)
1C53:07D6 7408          JZ  07E0        ; might be Windows broadcast
1C53:07D8 80FC46        CMP AH,46       ; INT 2Fh AH=46h?
1C53:07DB 7503          JNZ 07E0
1C53:07DD E93E01        JMP 0926
1C53:07E0 EA05007000    JMP 0070:0005   ; see if IO.SYS wants it
```

But look at it this looks rough after a few minutes it becomes clear that the quality of the disassembly is extremely poor. Much better versions of these INT 21h and INT 2Fh handlers is shown in Listings 6-1 and 6-2. For example, the most important part of the INT 21h handler uses the function number in AH as an index into a dispatch table:

```
;;; previously moved AH func number into BX
6A76:04FE 889FA73E      MOV BX,[BX+3EA7]
6A76:0502 36871EEA05    XCHG BX,SS:[05EA]
6A76:0507 368E1EEC05    MOV DS,SS:[05EC]
6A76:050C 36FF16EA05    CALL SS:[05EA]
```

I don't mean to go and look at 3EA7h (presumably the address of the all important INT 21h function dispatch table) there turns out instead to be perfectly valid looking code at that address, and not a table at all. Likewise 0514h and 05E4h are in this context totally bogus. This isn't a

problem with DOS 6 however A straight disassembly of MSDOS SYS or IO SYS created with a more sophisticated disassembler such as Source doesn't produce very good results

The problem is that MSINIT processes described in the *MS-DOS 6 Technical Reference* manuals are used to relocate code and segment addresses in the DOS kernel that won't match up properly with a disassembly of MSDOS SYS on disk To get a good disassembly of the core DOS startup handlers it is much easier to disassemble DOS in memory after the DOS initialization segment has completed but right inside the DOS HIGH routine that moves the DOS kernel into the high memory area, or HMA, is complete

The only problem with disassembling DOS out of memory rather than from the system files on disk is that this misses the MSINIT code which is discarded from memory when the initialization is complete However as noted earlier MSINIT and the DOS bootstrap process are handled well adequately covered elsewhere

Again if you compare the NOP instructions at the beginning of the protected startup routine in DOS 6 0 with those in DOS 6 2 you'll see that the 6 2 version has been patched with the code that uses the extra space for some undocumented purpose which is easy enough to find out we could have a look at the code in IO SYS that preloads DBLSPACE BIN However it seems we ought to take a look at this

Examining How IO.SYS Preloads DBLSPACE.BIN

It turns out that static disassembly of IO SYS is actually pretty easy even though at first glance the results produced by a disassembler such as Source look inadequate It's true that references to data don't match up with the actual locations of the data in the file, but once you match up just one piece of data in the file with code that references it you can figure out everything else

For example, a Source disassembly of IO SYS from MS DOS 6 0 contains the following data item

```
548F:8138  5C 44 42 4C 53 50 41 43     db      '\DBLSPACE.BIN'
548F:8145  45 2E 42 49 4E 00
```

This is followed shortly by code that based on the surrounding context (the code calls the INT 21h AX=4B03h Load Overlay function), is probably loading DBLSPACE.BIN However the code does not reference offset 8138h Instead it references CS:3B62h

```
548F:8153  0E              push cs
548F:8154  1F              pop ds
548F:8155  BE 3B62         mov si,3B62h
```

If you subtract 3B62h from 8138h, you get 45D6h If the code at 548F:8155 really is referencing the DBLSPACE.BIN string at offset 8138h then 45D6h is the amount which you must add to other data references in this version of IO.SYS in order to locate the data itself To see if this amount is accurate just look for another data reference and see if adding the amount onto it yields a likely looking address For example a little further on in the file IO.SYS produces an error message

```
548F:81E9  0E              push cs
548F:81EA  1F              pop ds
548F:81EB  BA 5823         mov dx,5823h
548F:81EE  B4 09           mov ah,9
548F:81F0  CD 21           int 21h      ; DOS Services  ah=function 09h
                                        ;  display char string at ds:dx
```

From the helpful comment supplied by Sourcer on how INT 21h AH=9 works, it is clear that 5823h must be the offset within CS of a string. Adding 45D6h to 5823h yields 9DF9h and there, indeed, is an error message

```
54BF:9DF9  57 72 6F 6E 67 20     db  'Wrong DBLSPACE.BIN version', 0Dh
```

Thus we really can pick apart IO.SYS on disk. This lets us examine the DOS boot process, in particular the recent additions such as the preloading of DBLSPACE.BIN in DOS 6 and the apparent ability to preload DOS386.EXE in DOS 7. "Preloading" means that IO.SYS looks for and loads these external programs before processing any DEVICE= statements in CONFIG.SYS. Chapter 1 discussed how Stacker 3.1 uses this interface to get itself preloaded under DOS 6. By examining IO.SYS you can see how the interface works.

For example, after calling INT 21h AX=4B03h to load DBLSPACE.BIN, IO.SYS looks for a function pointer at offset 14h in DBLSPACE.BIN:

```
54BF:81F1  E8 FB06                call    LOAD_OVERLAY    ; subr. does 21/4B03
;
54BF:81F4  2E  C7 06 0387 0014    mov word ptr cs:[387h],14h ; get func ptr from
54BF:81FD  2E  8C 06 0389         mov word ptr cs:[389h],es  ;   offset 14h
;                                                            ;   in DBLSPACE.BIN
```

IO.SYS saves away the function pointer provided by DBLSPACE.BIN, and then calls it:

```
54BF:81DA  0E                     push cs           ; IO.SYS passes DBLSPACE.BIN
54BF:81DB  07                     pop es            ;   a pointer to a buffer:
54BF:81DC  BB 036A                mov bx,36Ah       ; 36Ah+4506h=4940h (see below)
54BF:81DF  B8 0006                mov ax,6          ; DOS version
54BF:81E2  2E  FF 1E 0387         call dword ptr cs:[387h] ; call DBLSPACE.BIN
;                                                          ;   function ptr

54BF:8228  BB 0004                mov bx,4                 ; subfunction 4
54BF:822B  2E  FF 1E 0387         call dword ptr cs:[387h]
;
54BF:4940    8 00                 db   18h, 00h  , a communications buffer
```

IO.SYS also checks for a 2E2Ch signature at offset 12 in DBLSPACE.BIN. A hex dump of DBLSPACE.BIN reveals the presence of this signature:

```
C:\UNDOC>CHAPdump \dos\dblspace.bin /bytes 32
0000:  FF FF FF FF 42 48 41 08 BB 08 01 44 42 4C 53 50 |  . .BHA .. DBLSP
0010:  41 43 2C 2E E9 B2 59 00 00 EA 41 08 00 00 EA BB | AC,.. Y  .A..
```

Further discussion of this interface and its possible role in the ongoing battle between Microsoft and Stac Electronics appears in Chapter 1. Here, the point is simply that all existing descriptions of the DOS boot process will need to be rewritten to take into account new additions to DOS such as DBLSPACE.BIN (and, in DOS 7, DOS386.EXE).

Even a cursory look at IO.SYS reveals a marked change in the INT 21h dispatch code, which is executed each time a program makes a DOS call (except for another program that hooks INT 21h has completely bypassed IO.SYS's code). As we'll see, there are many important aspects to the INT 21h dispatch code, including stack switching, use of the current PSP, incrementing and decrementing the DOS flag handling of critical sections, Ctrl-Break and critical errors checking, the machine's A20 line, which DOS=HIGH and special casing for Windows Enhanced mode.

Interrupt Vectors and Chaining

Studying DOS internals requires finding the code in DOS that handles software interrupts such as INT 21h and INT 2Fh. As we just saw, trying to do this with IO.SYS and MSDOS.SYS on disk can produce inadequate results. In memory, however, a second-level INT can be used to find DOS's INT 21h and INT 2Fh handlers. As every PC programmer knows, there is a documented DOS function, INT 21h AH=35h, which returns in ES:BX a far pointer to the code that handles the interrupt given in AL.

Finding the current handlers for INT 21h and INT 2Fh is thus a simple matter of calling INT 21h AX=3521h and AX=352Fh and looking at the returned far pointer or vector as it's called. This can be wrapped up in a simple program to print out interrupt vectors. Add a little extra smarts, such as trying to figure out the *owner* of each interrupt vector and disassembling some (especially scrambled) instructions at the beginning of the interrupt handler, and the result is INTVECT.C, as shown in Listing 6-1. Listing 6-2 shows MAP.C, which attempts to figure out owners.

Listing 6-1: INTVECT.C

```
/*
INTVECT.C
bcc intvect.c map.c
*/

#include <stdlib.h>
#include <stdio.h>
#include <dos.h>

typedef unsigned char BYTE;
typedef unsigned short WORD;
typedef unsigned long DWORD;

#define MK_LIN(fp)  ((((DWORD) FP_SEG(fp)) << 4) + FP_OFF(fp))

extern char *find_owner(DWORD lin_addr);    // in map.c

#define ARPL    0x63
#define IRET    0xCF
#define JMPF    0xEA
#define JMP8    0xEB
#define JMP16   0xE9

BYTE far *get_vect(int intno)   // call INT 21h AH=35h
{
    _asm push es
    _asm mov al, byte ptr intno
    _asm mov ah, 35h
    _asm int 21h
    _asm mov dx, es
    _asm mov ax, bx
    _asm pop es
    // return value in DX:AX
}

void print_vect(int intno)
{
    char *s;
    BYTE far *fp = get_vect(intno);
    printf("INT %02Xh   %Fp   ", intno, fp);
    if (fp == 0)
    {
        printf("unused\n");
        return;
```

```
    }
    s = find_owner(MK_LIN(fp));
    printf("  08s     , s? s.    ),

    switch (*fp)    // see if first instruction of interrupt handler
    {               // is anything really obvious
        case ARPL   printf("arpl -- Windows V86 breakpoint"), break;
        case IRET   printf("iret -- NOP function"), break,
        case JMP8   printf(" jmp %Fp ,
            ((BYTE far *) fp) + fp[1] + 2), break,
        case JMP16  printf("jmp %Fp",
            ((BYTE far *) fp) + *((WORD far *) &fp[1]) + 3), break,
        case JMPF:  printf("jmp %Fp",
            *((void far * far *) &fp[1])); break;
    }
    printf(  r ),
}

main(int argc, char *argv[])
{
    char *end,
    int intno, i,
    if  argc < 2)
        for (intno) 0, intno<256; intno++)
            pr nt vect(intno),
    e.se for (i=1, i<argc; i++)
        print vect(strtoul(argv[i], &end, 16));
    return 0,
}
```

For example

```
C \UNDOC2\CHAP6>intvect 21 28 2f 24
INT 21h   C0B6 0942
INT 28h   1804:0615   PRINT
INT 29h   0070:0762   10
INT 2Fh   1A82 0000   NLSFUNC
```

INTVECT and Windows

If you run INTVECT without command line parameters it dumps out the vectors for all 256 interrupts. This is useful, for example, in determining which interrupts Windows Enhanced mode takes over. You can run INTVECT > TMP.TMP, start Windows, run INTVECT > TMP.2 from inside a DOS box, and then use diff or a similar utility to compare the files TMP.TMP and TMP.2. The difference between these two files reveals the interrupts that Windows enhanced mode hooks using the low memory interrupt vector table (it also hooks some interrupts using the protected mode interrupt descriptor table). Where < points to the pre-Windows DOS output from INTVECT, and > points to the output under Windows, part of the output from diff might look like this (the complete output also shows changes to INT 0, 3, 8, 10h, 15h, 1Ch, 22h, 23h, 24h, 67h, and 68h):

```
< INT 28h   07F9:15AE   SMARTDRV
> INT 28h   FEF8:0B62   DBLSSYS$   arpl -- Windows V86 breakpoint

< INT 2Fh   1305:0285   DOSKEY
> INT 2Fh   1627:02A7   win

< INT 4Bh   F000:EA97   DBLSSYS$
> INT 4Bh   FEE1:0ED2   DBLSSYS$   arpl -- Windows V86 breakpoint
```

INT 28h is the DOS idle interrupt and the Virtual DMA Services (VDS) use INT 4Bh. As you can see, INTVECT examines the first byte of an interrupt handler looking for code such as the ARPL instruction which Windows Enhanced mode uses as a V86 breakpoint to force a transition from user (Ring 3) code to VMM (Ring 0) code. The seeming location of the Windows V86 breakpoints inside DBLSSYS$ (DoubleSpace) is misleading. This has to do with the way Windows implements V86 breakpoints (see Chappell, *DOS Internals*, Chapter 2).

To build INTVECT, INTVECT.C should be linked with MAP.C (Listing 6-2). MAP.C attempts to provide the owner's name for each interrupt vector using code that was explained in detail in Chapter 5. We will reuse MAP.C in other programs also in this chapter. INTCHAIN.C (Listing 6-5) MAP.C can also be compiled with DTESTING to produce a stand-alone program. For example, running MAP.EXE on my machine happened to produce the following output which shows that this machine is running DoubleSpace, MSCDEX, SMARTDRV loaded high, DOSKEY also loaded high, and XMS and EMM servers.

```
C:\UNDOC2\CHAP6>map
00000700    000009A0   IO
000009A0    00001E80   DOS
00001E80    00002010   D:
00002010    00005780   MS$MOUSE
00005780    00007EA0   MSCD001
00007EA0    00012FA0   DBLSSYS$
00012FA0    000131F0   $ETVERXX
000131F0    00013670   XMSXXXX0
00013670    00014950   EMMXXXX0
00014950    000189A0   MSCDEX
000189A0    0002A7E0   MAP
000CAA30    000CBBA0   COMMAND
000CBB00    000D2C60   SMARTDRV
000CDDA2    000CDDB4   M
000CDDB4    000DE470   J
000DE470    000DF4A0   DOSKEY
00100000    0010FFEE   HMA
```

Listing 6-2: MAP.C

```
/*
MAP.C
bcc intvect.c map.c
bcc intchain.c map.c
bcc -DTESTING map.c
*/

#include <stdlib.h>
#include <stdio.h>
#include <string.h>
#include <dos.h>

typedef unsigned char BYTE;
typedef unsigned short WORD;
typedef unsigned long DWORD;
typedef void far *FP;

#ifndef MK_FP
#define MK_FP(s,o)      ((((DWORD) s) << 16) + (o))
#endif

#pragma pack(1)
```

```
typedef struct {
    DWORD start, end;
    char name[9];
    } BLOCK;

static BLOCK *map;
static int num_block = 0;

int cmp_func(const void *b1, const void *b2)
{
    if (((BLOCK *) b1)->start < ((BLOCK *) b2)->start)       return -1;
    else if (((BLOCK *) b1)->start > ((BLOCK *) b2)->start)  return 1;
    else                                                     return 0;
}

typedef struct {
    BYTE type;          /* 'M'=in chain; 'Z'=at end */
    WORD owner;         /* PSP of the owner */
    WORD s ze,          /* in 16-byte paragraphs */
    BYTE unused[3];
    BYTE name[8],       /* in DOS 4+ */
    } MCB,

#define IS_PSP(mcb)     (FP_SEG(mcb) + 1 == (mcb)->owner)

WORD get first mcb(void)
{
    _asm mov ah, 52h
    _asm int 21h
    _asm mov ax, es:[bx-2]
    // retval in AX
}

typedef struct DEV {
    struct DEV far *next,
    WORD attr, strategy, intr;
    union {
        BYTE name[8], blk_cnt;
        } u;
    } DEV,

#define IS_CHAR DEV(dev)    ((dev)->attr & (1 << 15))

DEV far *get_nul_dev(void)
{
     asm mov ah, 52h
     asm int 21h
     asm mov dx, es
    _asm lea ax, [bx+22h]
    // retval in DX AX
}

int get_num_block_dev(DEV far *dev)
{
    // can't rely on # block devices at SysVars[20h]
    // walk once through dev chain just to count # blk devs
    int num_blk = 0;
    do {
        if (! IS_CHAR_DEV(dev))
            num_blk += dev->u.blk_cnt,
        dev = dev->next,
    } while(FP_OFF(dev->next) != (WORD) -1);
    return num_blk;
}
```

```
WORD get_umb_link(void)
{
    _asm mov ax, 5802h
    _asm int 21h
    _asm xor ah, ah
    // return value in AX
}

WORD set_umb_link(WORD flag)
{
    _asm mov ax, 5803h
    _asm mov bx, flag
    _asm int 21h
    _asm jc error
    _asm xor ax, ax
error:;
    // return 0 or error code in AX
}

WORD get_dos_ds(void)
{
    _asm push ds
    _asm mov ax, 1203h
    _asm int 2fh
    _asm mov ax, ds
    _asm pop ds
    // retval in AX
}

/* find IO.SYS segment with built-in drivers */
WORD get_io_seg(DEV far *dev)
{
    WORD io_seg = 0;
    do {
        if (IS_CHAR_DEV(dev))
            if (_fstrncmp(dev->u.name, "CON     ", 8) == 0)
                io_seg = FP_SEG(dev);   // we'll take the last one
        dev = dev->next;
    } while(FP_OFF(dev->next) != (WORD) -1);
    return io_seg;
}

static int did_init = 0;

void do_init(void)
{
    MCB far *mcb;
    DEV far *dev = get_nul_dev();
    WORD dos_ds, io_seg, mcb_seg, next_seg, save_link;
    BLOCK *block;
    int blk, i;

    map = (BLOCK *) calloc(100, sizeof(BLOCK));
    block = map;

    io_seg = get_io_seg(dev);
    block->start = io_seg << 4; block->end = (DWORD) -1;
    strcpy(block->name, "IO"); block++;

    dos_ds = get_dos_ds();
    block->start = dos_ds << 4; block->end = (DWORD) -1;
    strcpy(block->name, "DOS"); block++;

    // should really check if there IS an HMA!
    block->start   0x100000L;   block->end =  0x10FFEEL;
```

```
strcpy(block->name, "HMA"); block++;
num_block = 3;

/* walk MCB chain, looking for PSPs, interrupt owners */
if (_osmajor >= 4)
{
    mcb_seg = get_first_mcb();
    mcb = (MCB far *) MK_FP(mcb_seg, 0);
    if ( osmajor >= 5)  // be lazy, see ch  7 for DOS < 5
    {
        save_link = get_umb_link();
        set_umb_link(1);    // access UMBs too
    }

    for (;;)
    {
        next_seg = mcb_seg + mcb->size + 1;
        if (IS_PSP(mcb))
        {
            block->start = ((DWORD) mcb_seg) << 4;
            block->end = ((DWORD) next_seg) << 4;
            _fstrncpy(block->name, mcb->name, 8);
            block->name[8] = '\0';
            block++, num_block++;
        }
        mcb_seg = next_seg;
        if (mcb->type == 'M')
            mcb = (MCB far *) MK_FP(next_seg, 0);
        else
            break;
    }
}

/* walk dev ch chain looking for non-builtin drivers */
blk = (get_num_block dev(dev),
do {
    MCB far *dev_mcb;
    if ((FP_SEG(dev) != dos_ds) && (FP_SEG(dev) != io_seg))
    {
        block->start = (((DWORD) FP_SEG(dev)) << 4) + FP_OFF(dev);
        dev_mcb = (MCB far *) MK_FP(FP_SEG(dev)-1,0);
        if (dev_mcb->owner == 8)
        {
            dev = dev->next;
            continue;
        }
        if (dev_mcb->type == 'M')
            block->end = block->start + ((DWORD) dev_mcb->size << 4);
        else
            block->end = (DWORD) -1;
        if (IS_CHAR_DEV(dev))
        {
             fstrncpy(block->name, dev->u_name, 8);
            block->name[8] = '\0';
        }
        else
        {
            blk -= dev->u_blk_cnt; // block drivers in reverse order
            block->name[0] = blk + 'A';
            block->name[1] = ':';
            block->name[2] = '\0';
        }
        block++; num_block++;
    }
    dev = dev->next;
```

```
    } while(FP_OFF(dev->next) != (WORD) -1);

    if (_osmajor >= 5)
        set_umb_link(save_link);

    qsort(map, num_block, sizeof(BLOCK), cmp_func);

    for (i=0, block=map, i<num_block-1, i++, block++)
        if (block->end == (DWORD) -1)
            block->end = map[i+1].start;
    if (block->end == (DWORD) -1)   // last one
        block->end = 0xFFFFFL;

    did_init = 1;
}

char *find_owner(DWORD lin_addr)
{
    BLOCK *block;
    int i;

    if (! did_init) do_init();

    for (i=0, block=map, i<num_block; i++, block++)
        if ((lin_addr >= block->start) &&
            (lin_addr <= block->end))
            return block->name;

    /* still here */
    return (char *) 0;
}

#ifdef TESTING
main()
{
    BLOCK *block;
    int i;
    do_init();
    for (i=0, block=map, i<num_block, i++, block++)
        printf("%08lX   %08lX   %s\n",
            block->start, block->end, block->name);
}
#endif
```

With the exception of unused interrupt vectors and those, such as INT 1Ah, that point to data rather than code, you can take addresses displayed by INTVEC and disassemble them to see how a given interrupt is implemented. As an example, Figure 6-1 shows INT 29h, which is the undocumented Fast Console Output function used by default in the CON driver provided by DOS.

Figure 6-1: Default implementation of INT 29h

```
C:\UNDOC2\CHAP6>intvect 29
INT 29h   0070:0762   IO

C:\UNDOC2\CHAP6>debug
-u 70:762
0070:0762 50            PUSH  AX
0070:0763 56            PUSH  SI
0070:0764 57            PUSH  DI
0070:0765 55            PUSH  BP
0070:0766 53            PUSH  BX
0070:0767 B40E          MOV   AH,0E
0070:0769 BB0700        MOV   BX,0007
0070:076C CD10          INT   10
```

```
0070:076E 5B            POP   BX
0070:076F 5D            POP   BP
0070:0770 5F            POP   DI
0070:0771 5E            POP   SI
0070:0772 58            POP   AX
0070:0773 CF            IRET
```

That is, as a straightforward INT 29h here is just a wrapper around INT 10h AH=0Eh, which is the BIOS TTY function to write a character in teletype mode.

Of course, things aren't always that simple. For example, if you install ANSI.SYS, which is a replacement CON driver, INT 29h points somewhere else:

```
C:\UNDOC2\CHAP6>intvect 29
INT 29h   0070:0762

C:\UNDOC2\CHAP6>undoc2\chap7\devload \dos\ansi.sys

C:\UNDOC2\CHAP6>intvect 29
INT 29h   6883:0510   DEVLOD
```

Because we loaded ANSI.SYS using DEVLOD, the INTVEC program shows DEVLOD as the owner of the interrupt vector. The owner, of course, is actually the new CON driver in ANSI.SYS. Now, instead of the BIOS INT 10h wrapper, we get a wrapper around an INT 10h call. Instead, it directly manipulates video memory. Except for BIOS and certain special handling for ANSI escape control codes, writing characters to the screen is a fairly complex task for a chapter such as this that rambles more or less and stays away from the DOS code. The point, anyway, is merely that the INTVEC program simply reports what it finds in the IVT. It doesn't look segment:offset addresses to unassemble.

Before we run into a major problem here. Recall that we are interested in looking at the DOS INT 21h and INT 2Fh handlers. INTVEC can, of course, print out the addresses of the INT 21h and INT 2Fh handlers:

```
C:\UNDOC2\CHAP6>intvect 21 2f
INT 21h   0F93:3286   MSCDEX
INT 2Fh   1305:0285   DOSKEY
```

However, as INTVEC indicates, these interrupt vectors point not to DOS but to DOS add-ins such as MSCDEX and DOSKEY. In fact, it is practically *guaranteed* that, except on the latest, freshly booted, unpopulated system, such as AUTOEXEC.BAT or CONFIG.SYS, the INT 21h, INT 2Fh, and many other DOS interrupt vectors will point into DOS. The INT 21h and INT 2Fh vectors are pointing at one of the programs' code segments rather than at the DOS motherboard.

Of course, if you're interested in examining MSCDEX's INT 2Fh handler or DOSKEY's INT 2Fh handler, the INTVEC program is very useful. It provides all the information needed by a debugger such as DEBUG or SYMDEB, a handy debugger that Microsoft once included with the Windows SDK. For example, by using DEBUG or SYMDEB to unassemble the 1305:0285 address displayed by INTVEC for INT 2Fh, we can see that DOSKEY watches for the Windows and task switcher multiplex broadcasts, INT 2Fh AX=1605h and AX=4805h. DOSKEY clearly uses the same piece of code, even at offset 0299h, to handle both calls. We can also see confirmation that, as documented in Microsoft's *MS-DOS Programmer's Reference*, DOSKEY responds to INT 2Fh AH=48h calls:

```
C:\UNDOC2\CHAP6>intvect 2f
INT 2Fh   1305:0285   DOSKEY
C:\UNDOC2\CHAP6>debug
-u 1305:0285
1305:0285 3D0516        CMP   AX,1605
1305:0288 7409          JZ    0299
1305:028A 3D0548        CMP   AX,4805
1305:028D 7404          JZ    0299
1305:028F 80FC48        CMP   AH,48
```

```
1305:0292 741B          JZ      02AF
1305:0294 2EFF2E5F02    JMP     FAR CS:[025F]
; ...
```

But if, for example, we want to see MSCDEX's INT 2Fh handler rather than DOSKEY's, and if DOSKEY is loaded after MSCDEX, INT2FCL is of no use. Note, however, that unlike MSDOS.SYS and IO.SYS programs such as MSCDEX.EXE and DOSKEY.EXE are easy to disassemble or disk utility programs such as Sourcer from V Communications.

More important, the INT2FCL doesn't help us get the address of what we might call the One True INT 21h Handler inside MSDOS.SYS. Nor does it help with finding the original INT 21h handlers inside MSDOS.SYS and IO.SYS.

Why? Because interrupts are handled as a kind of last in, first out (LIFO) stack. The point was made at the beginning of this chapter that the DOS philosophy is to provide the bare minimum operating system services, along with facilities for *extending* DOS. As discussed in greater detail in Chapter 9 on TSRs, one of the keys to extending DOS is INT 21h AH=25h, the DOS Set Interrupt Vector function. Along with the Get Interrupt Vector function, AH=35h, the Set Vector function allows the creation of what are called interrupt chains, which are essentially linked lists, or LIFO stacks, of code. An interrupt chain consists of two or more pieces of code that handle the same interrupt. The following code fragment, adapted from the FUNC0B.32 and DOSVER programs in Listings 2.20 and 2.21, illustrates this:

```
void (interrupt far *prev)(),              // ptr to previous handler in chain
prev = _dos_getvect(0x21),                 // call 21/35 - get previous
_dos_setvect(0x21, my_int21_handler),      // call 21/25 -- set new
// ...
void interrupt far my_int21_handler(REG_PARAMS r)
{
    // look at AH to see if we're interested
    // ...
    _chain_intr(prev);  // pass interrupt down to previous owner in chain
}
```

The `_chain_intr` call is a far JMP to the previous interrupt handler in the chain, without returning. It is important to note that some interrupt handlers CALL rather than JMP to the previous handler. This is as a handler to post process the interrupt *after* the previous handler has done its work rather than to pre-processing the interrupt before, and which is what happens in the more typical JMP style of interrupt chaining. Sometimes the JMP style code is called a front end handler and the CALL style code is called a back end handler.

It is especially important that INT 21h AH=25h and 35h allow you to *hook* INT 21h itself. This is a source of tremendous flexibility in DOS, but it also makes it difficult for us to find The One True INT 21h Handler. Calling INT 21h AX=3521h gives us the address of the INT 21h linked list, that is, the address of the most recently installed INT 21h handler. This might conceivably be the genuine DOS INT 21h handler, but more likely it belongs to MSCDEX, NLSFUNC or perhaps even a utility such as the FUNC0B.32 or DOSVER programs from Chapter 2. INT 21h AX=3521h simply returns the *head* of an interrupt chain. Finding the original INT 21h or INT 2Fh handler belonging to DOS usually requires finding the chain's *tail*. (Usually rather than always because there might be back end handlers.)

How can we find the actual INT 21h and INT 2Fh handlers provided by DOS itself? What we have is the address of the head of the INT 21h or INT 2Fh interrupt chain. There is, unfortunately, no function call that returns the tail of an interrupt chain. And while there is an undocumented DOS function, INT 2Fh AX=1203h, to return the DOS data segment, there is no equivalent function that returns the DOS code segment, which, remember, may well be in the HMA.

One solution would, of course, be to boot on an absolutely bare bones system. I hope that INT 21h and INT 2Fh point to the original MS-DOS handlers, thereby bypassing the whole pro-

...or how to follow interrupt chains. Or you could write a device driver to keep track of interrupts and install it very early in DOS initialization. But this is ridiculous! Clearly there must be some way to ...out the interrupt chain as the processor does this many times a second.

Unfortunately, there's no standard mechanism for interrupt chaining. IBM and Microsoft at one point ... put forward a specification for this purpose. David Burden discussed it in detail in *Microsoft Systems Journal* (July 1992, pp. 24-28), but unfortunately no one seems to use it. Ralf Brown has proposed ...INT 2Fh protocol described in the Interrupt List on disk to combat the extremely long interrupt chains that currently plague INT 21h, but again you can't rely on programs to do the right thing and use this protocol.

Tracing a DOS INT 21h Call

It turns out that Microsoft provides with every copy of DOS an almost perfect solution to the problem of tracing through DOS INT 21h and INT 2Fh handlers. The solution is none other than DEBUG.

...ost versions of DEBUG have a T command to execute instructions one by one and a P command to execute CALL, LOOP, and INT instructions as opposed to stepping over instructions. Even better, unlike some other single-step debuggers, the T command in DEBUG can trace *into* an INT instruction. For example, most of the DOS kernel runs with DEBUG does not treat INT as an atomic operation:

```
C:\UNDOC2\CHAP6>intvect 21
INT 21h   0F93:3286   MSCDEX

C:\UNDOC2\CHAP6>debug
-a
1985:0100 mov ah,62
1985:0102 int 21
1985:0104 ret
1985:0105
-t

AX=6200  BX=0000  CX=0000  DX=0000  SP=FFEE  BP=0000  SI=0000  DI=0000
DS=1985  ES=1985  SS=1985  CS=1985  IP=0102   NV UP EI PL NZ NA PO NC
1985:0102 CD21          INT 21
-t

AX=6200  BX=0000  CX=0000  DX=0000  SP=FFE8  BP=0000  SI=0000  DI=0000
DS=1985  ES=1985  SS=1985  CS=0F93  IP=3286   NV UP DI PL NZ NA PO NC
0F93:3286 80FC60        CMP AH,60
```

Notice that pressing *t* at the INT 21h instruction took us into the first line of the handler at 0F93:3286. (The handler turned out to be MSCDEX.) Instruction at 1985:0104 This is exactly what one might expect to happen if you hit the *p* prompt. (It's because of the way the single-step interrupt works on the processor; see INT1TRAP.ASM, a listing that's later in this chapter.) Most debuggers don't ...this because it's such a pain to step through DOS. Unless you have a copy of DOS's source code, which DEBUG does.

...Now you have two options: to follow the INT 2Fh or INT 21h chain down into the bowels of DOS itself. Yuck. Almost always, you'll want to keep tracing, either by continually pressing *t* or by telling DEBUG to trace a certain number of instructions, until the segment of the current instruction (CS in DEBUG) and the IRET instruction which, in the example above, is located at 9C60:0004 ...is what you're looking for. That is, DOS INT 21h or INT 2Fh handler.

However, I'm sure the astute reader is with me on this one right now: before we go any farther than using DEBUG to trace into INT 2Fh, I must point out that DEBUG itself uses DOS and DOS, as we all know, is not reentrant. This is absolutely true. A debugger that does not use DOS, such as Nu Mega's SoftICE, is better suited than DEBUG to tracing through DOS.

However, there are a handful of DOS functions that *are* reentrant, at least for the purposes of tracing with DEBUG. By examining the DOS code for INT 21h, we will soon see precisely what this reentrancy or lack thereof means. In the meantime, simply take it on faith that the DOS INT 21h functions shown in Table 6-1 are safe to trace with an important caveat that we'll get to in a moment and thus traceable using DEBUG, SYMDEB, or another debugger that uses DOS. With the exception of the undocumented INT 21h AH=64h, note that these are among the INT 21h functions that Microsoft *MS-DOS Programmer's Reference* Chapter 7 lists as callable from a critical error handler.

Table 6-1: Reentrant MS-DOS Functions

INT 21h AH=33h	(Get/Set Ctrl-Break, Get Boot Drive, Get DOS Version)
INT 21h AH=51h and AH=62h	(Get PSP)
INT 21h AH=50h	(Set PSP)
INT 21h AH=64h	(Set Driver Look-ahead Flag)

Note: Because it contains many DOS HLOCK and the 4201 bug, is disabled

It is desirable for MS-DOS to support not only Get and Set PSP functions for special treatment because this is essential for interrupt handlers can freely call these process manipulation functions (see Chapter 8). The INRs—Boot—is not always provided by functions 50h and 64h (more on this special attention). It would seem that these functions such as AH=25h and AH=35h to get and set interrupt vectors, might be reentrant. On the other hand, invoking function 33h here means that interrupt handlers can freely get and set the DOS BREAK flag.

Let us now use DEBUG to trace a call to one of these functions, INT 21h AH=62h (Get PSP) and see exactly what occurs when this function is called under DOS 6.0 in its configuration with a few standard DOS TSRs such as MSCDEX and DOSKEY. The documentation states that function 62h takes no parameters except that the number 62h in AH and that the function returns the current PSP in BX. You can probably guess that the DOS implementation of this function is rather simple, consisting of one or two instructions to return the current PSP location in the DOS variable segment. This location can of course change. Once the Swappable Data Area (SDA, see INT 21h AX=5D06h) is supported. However, you will see the processor executes not a single code within DOS except for. It gets out of a piece of cake, but the other two simple Get PSP ops are.

We noted earlier that the key to DEBUG's power here is that using SYMDEB to trace steps traces *into* the INT instruction. In Figure 6-2, comments have been added to the DEBUG output, using ;;; to make them stand out.

Figure 6-2: Starting to Trace a Call to INT 21h AH=62h

```
C:\UNDOC2\CHAP6>debug
-a
1985:0100 mov ah, 62
1985:0102 int 21
1985:0104 ret
1985:0105
-t

AX=6200  BX=0000  CX=0000  DX=0000  SP=FFEE  BP=0000  SI=0000  DI=0000
DS=1985  ES=1985  SS=1985  CS=1985  IP=0102   NV UP EI PL NZ NA PO NC
1985:0102 CD21          INT 21
-t

;;; We have to keep tracing until the segment offset comes back to
;;; our own code, the RET instruction at 1985:0104

AX=6200  BX=0000  CX=0000  DX=0000  SP=FFEE  BP=0000  SI=0000  DI=0000
DS=1985  ES=1985  SS=1985  CS=DF93  IP=32B6   NV UP DI PL NZ NA PO NC
DF93:32B6 80FC60        CMP AH,60
```

```
-t

;;  Running MEM /D showed that above is MSCDEX  This is consistent
;   with output from INTVECT program  Apparently MSCDEX is interested
;;  in the undocumented DOS INT 21h AH=60h (Truename) function  Note that
;   we were running MSCDEX /S (for network sharing,, usually MSCDEX doesn't
;;; care about the INT 21h AH=60h call

AX=6200  BX=0000  CX=0000  DX=0000  SP=FFE8  BP=0000  SI=0000  DI=0000
DS=19B5  ES=19B5  SS=19B5  CS=0F93  IP=3289   NV UP DI PL NZ NA PO NC
0F93:3289 7405          JZ  3290
-t

AX 6200  BX 0000  CX=0000  DX=0000  SP=FFE8  BP=0000  SI=0000  DI=0000
DS=19B5  ES=19B5  SS=19B5  CS=0F93  IP=3288   NV UP DI PL NZ NA PO NC
0F93 3288 2E            CS:
0F93 328C FF2EB232      JMP FAR [3282]                          CS:3282=15FA
-t

;;; MSCDEX decided it's not interested in our call to 21/62, so it chains
;;; to the previous handler  whose address it earlier retrieved (by
;;; calling 21/35) and saved away (apparently in CS:3282) before installing
;;; (with 21/25) its own INT 21h handler.

AX 6200  BX 0000  CX=0000  DX=0000  SP=FFE8  BP=0000  SI=0000  DI=0000
DS=19B5  ES=19B5  SS=19B5  CS=07F9  IP=15FA   NV UP DI PL NZ NA PO NC
07F9:15FA 80FC3F        CMP AH,3F

;;  We're now in the previous INT 21h handler  MEM /D shows that
;;  07F9 15FA is SMARTDRV  Here it's (reasonably enough) interested in
;;  whether we've called INT 21h AH=3Fh to read from a file  (SMARTDRV
;;; wants to see if the data we want from the file is actually already
;;; in its cache )  But we called 21/62 not 21/3F so...
```

Well, you get the idea. Running DEBUG this way is a bit tedious and saving its output to a file is a real pain. With a little more work, you can drive DEBUG with input scripts such as 2162.SCR in Listing 6-3 and collect its output in a file. For a graphical discussion of DEBUG scripts, see *PC Magazine DOS Power Tools*, 2nd edition, Chapter 9. Furthermore, rather than repeatedly hitting *t* to trace single-step the next instruction, you can give the trace command a numeric parameter, for example *t 10* or *t 32*, to trace a series of instructions.

Listing 6-3. 2162.SCR

```
C:\UNDOC2\CHAP6>type 2162.scr
a
mov ah, 62
int 21
ret
, blank line below is crucial to leave assembly mode!

r 100
q
```

Here's the problem: I'm guessing how many instructions to trace. If you ask DEBUG to trace too far, it starts executing garbage. You only want to trace until you return to the RET instruction you assembled or at least not much past it. The best way is first try *t 10*, examine DEBUG's output to see if the traced instructions come back, then try *t 32*, examine the output again, and so on. In any case, *t 100* happened to work here; a larger number would be needed on machines with more TSRs that hook INT 21h installed.

Figure 6-3 shows a complete trace into an INT 21h AH=62h call, from the time we issued the INT 21h until DOS returns to us with the current PSP in BX. Normally all that you see (or want to

see what an INT 21h call's your input and its output. But Figure 6-3 views the DOS call through the looking glass, as it were. Instead of looking down at DOS, you'll be inside DOS looking up at the INT 21h call. It's an eye-opening, mind-boggling experience at first, but if you carefully study Figure 6-3 in the end you'll have a much better understanding of what DOS is all about.

Figure 6-3: Tracing a Call to INT 21h AH=62h

```
C:\UNDOC2\CHAP6>debug<2162.scr>2162.out

C:\UNDOC2\CHAP6>type 2162.out
-a
19B5:0100 mov ah, 62
19B5:0102 int 21
19B5:0104 ret
19B5:0105
-t 106

AX=6200  BX=0000  CX=0000  DX=0000  SP=FFEE  BP=0000  SI=0000  DI=0000
DS=19B5  ES=19B5  SS=19B5  CS=19B5  IP=0102   NV UP EI PL NZ NA PO NC
19B5:0102 CD21          INT 21

AX=6200  BX=0000  CX=0000  DX=0000  SP=FFE8  BP=0000  SI=0000  DI=0000
DS=19B5  ES=19B5  SS=19B5  CS=0F93  IP=32B6   NV UP DI PL NZ NA PO NC
0F93:32B6 80FC60        CMP AH,60

;;; As before (Figure 6-2), we're in MSCDEX /D now

AX=6200  BX=0000  CX=0000  DX=0000  SP=FFE8  BP=0000  SI=0000  DI=0000
DS=19B5  ES=19B5  SS=19B5  CS=0F93  IP=3289   NV UP DI PL NZ NA PO NC
0F93:3289 7405          JZ  3290

;;; The AX=xxxx BX=xxxx etc  dump that DEBUG shows each time usually
;;; isn't important here  so from now on we'll omit it  and blank lines,
;;; except when the register dump is useful

0F93:328B 2E            CS:
0F93:328C FF2E8232      JMP FAR [3282]                          CS:3282=15FA
07F9:15FA 80FC3F        CMP AH,3F

;;; As before, we're in SMARTDRV now

07F9:15FD 7414          JZ  1613
07F9:15FF 80FC0D        CMP AH,0D
07F9:1602 7426          JZ  162A
07F9:1604 3D1325        CMP AX,2513
07F9:1607 7451          JZ  165A
07F9:1609 80FC68        CMP AH,68
07F9:160C 7442          JZ  1650

;;; Above provides a catalog of the DOS INT 21h function calls that
;;; SMARTDRV cares about: 3Fh (read file), 0Dh (disk reset)  2513h
;;; (set INT 13h vector), 68h (commit file)  All this makes sense
;;; For example, SMARTDRV uses 21/0D as a signal to flush the cache
;;; For some calls, such as 21/0D, SMARTDRV doesn't JMP to the previous
;;; handler; instead, it does a far CALL and examines the 21/0D on
;;; the way back

07F9:160E 2E            CS:
07F9:160F FF2E1423      JMP FAR [2314]                          CS:2314=0800

;;; We called 21/62; SMARTDRV doesn't care, so SMARTDRV chains to
;;; previous handler, C801:0800, which SMARTDRV earlier got from
;;; calling 21/35 before installing its own 21 handler with 21/25, and
;;; which is stored in CS:2314
```

```
C801 0800 9C            PUSHF

;;, Was running with DOS=UMB, so some INT 21h handlers are running
; ; in upper memory  Don t know who the owner of this is!

C801 0801 FB            STI
C801.0802 3D0258        CMP AX,5802
C801 0805 7413          JZ  081A
C801.0807 3D0358        CMP AX,5803
C801 080A 7431          JZ  083D
C801:080C 80FC31        CMP AH,31
C801 080F 7503          JNZ 0814
C801 0814 9D            POPF

;;  We can see that this handler cares about calls to INT 21h functions
 ;; 5802h (Get UBN Link), 5803h (Set UMB Link), 31h (TSR)  Wonder why
;;; Anyway  we called 21/62; the handler isn t interested in that, so it
;;; chains to the previous handler

C801.0815 2E            CS:
C801 0816 FF2EC601      JMP FAR [01CE]                  CS:01CE=0023

0255:0023 EA8E052ECC    JMP CC2E:058E

;;  DEV shows that seg 0255h is a a block mode device driver for
;;; D: through I:    it is a low-memory stub for DoubleSpace, located in
 ;  high memory  Stacker uses the same area: both have signatures at
;   0255:0000  DEV also shows that CC2E:058E is DBLSYS$ (DoubleSpace)

CC2E:058E 9C            PUSHF
CC2E:058F FB            STI
CC2E:0590 FC            CLD
CC2E.0591 1E            PUSH    DS
CC2E:0592 0E            PUSH    CS
CC2E:0593 1F            POP DS
CC2E:0594 C606C20700    MOV BYTE PTR [07C2],00          DS:07C2=00
CC2E:0599 53            PUSH    BX
CC2E:059A 8ADC          MOV BL,AH
CC2E:059C 80FB6C        CMP BL,6C
CC2E:059F 7759          JA  05FA
CC2E:05A1 32FF          XOR BH,BH
CC2E:05A3 8A9F1305      MOV BL,[BX+0513]                DS:0575=00
CC2E:05A7 FFA78005      JMP [BX+0580]                   DS:0580=05FA

    Doub.eSpace is sufficiently tied into DOS that it uses a jump table to
; ; store a handler for every DOS function  The table at CC2E:0513 holds
;;  byte offsets into code at CC2E:0580. Most DOS functions (including
;;  our 21/62 call  are just passed on  Examining the table with the FTAB
    program from later in this chapter shows that DoubleSpace cares
;;  about the following INT 21h functions  00  0A  0D  10  13  17, 25  31,
; ; 36  39  3A  3E  41  43  4B  4C  56  57  5D, 6B  We know this from
;;  running "ftab cc2e 0513 6d DS:21 1 | grep -v 00"  For example, it hooks
;;  21/25 because (like SMARTDRV) it wants to know whenever someone sets the
;;; INT 13h (BIOS Disk) vector

CC2E:05FA 5B            POP BX
CC2E:05FB 1F            POP DS
CC2E:05FC 9D            POPF
CC2E:05FD 2E            CS
CC2E:05FE FF2E0005      JMP FAR [0500]                  CS:0500=109E

;;; Trivial handling for our 21/62 call. Pass it to previous handler .

0116:109E 90            NOP
```

```
;;; MEM /D shows that 0116h is MS-DOS. Finally!

0116:109F 90            NOP
0116:10A0 E8CC00        CALL    116F

;;; Hmm, DOS is calling some subroutine (which we've traced into)

0116:116F 9C            PUSHF
0116:1170 1E            PUSH    DS
0116:1171 06            PUSH    ES
0116:1172 51            PUSH    CX
0116:1173 56            PUSH    SI
0116:1174 57            PUSH    DI

;;; We need to see the registers for the next few instructions
;;; Note what happens to DS and ES

AX=6200  BX=0000  CX=0000  DX=0000  SP=FFDA  BP=0000  SI=0000  DI=0000
DS=19B5  ES=19B5  SS=19B5  CS=0116  IP=1175   NV UP DI NG NZ AC PE CY
0116:1175 2E            CS
0116:1176 C536671100    LDS SI,[1167]                           CS:1167=0080

AX=6200  BX=0000  CX=0000  DX=0000  SP=FFDA  BP=0000  SI=008D  DI=0000
DS=0000  ES=19B5  SS=19B5  CS=0116  IP=117A   NV UP DI NG NZ AC PE CY
0116:117A 2E            CS
0116:117B C43E681100    LES DI,[1168]                           CS:1168=0090

AX=6200  BX=0000  CX=0000  DX=0000  SP=FFDA  BP=0000  SI=0080  DI=0090
DS=0000  ES=FFFF  SS=19B5  CS=0116  IP=117F   NV UP DI NG NZ AC PE CY
0116:117F B90400        MOV CX,0004

0116:1182 FC            CLD
0116:1183 F3            REPZ
0116:1184 A7            CMPSW
0116:1185 7407          JZ  118E

;;; DOS has just compared 8 bytes (4 words) at DS:SI  0000:0080) and
;;; ES:DI  FFFF:0090   If they are identical  DOS jumps somewhere
;;; What is this?' This particular run of DEBUG was conducted with
;;; DOS=HIGH  DOS is in the HMA  which is only reachable when the
;;; machine's A20 address line is enabled  DOS is comparing 0000:0080
;;; and FFFF:0090 because  if the 8 bytes at these two addresses are
;;; identical  it assumes that memory addresses are wrapping around, and
;;; therefore that A20 is off  DOS can't call routines in the HMA if A20
;;; is off  Thus  even when DOS=HIGH there must be a low memory stub  the
;;; code at 0116:109E is that stub  which ensures that A20 is enabled before
;;;  calling DOS in the HMA  Here  A20 was already on  0000:0080 and
;;; FFFF:0090 were different), but A20 has been off; we would
;;; have  umped to the subroutine at 0116:118E  whose job
;;; is to enable A20  by calling XMS function 5  Local Enable A20)
;;; If that function call succeeds, DOS will jump back here  just as if
;;;  A20 had been enabled all along  If that function call fails, we're
;;; in big trouble  DOS uses INT 10h AH=0Eh to display "A20 Hardware
;;; Error" and goes into a dynamic halt  We'll come back to this
;;; code later  Right now, A20 is enabled so. .

0116:1187 5F            POP DI
0116:1188 5E            POP SI
0116:1189 59            POP CX
0116:118A 07            POP ES
0116:118B 1F            POP DS
0116:118C 9D            POPF
0116:118D C3            RET
0116:10A3 2E            CS
```

```
0116:10A4 FF2E6A10      JMP FAR [106A]                          CS:106A=40F8

;;; The low-memory stub for DOS knows it can jump to DOS in the HMA, and
;;; here we go:

FDC8:40F8 FA            CLI

;;; We are now in The One True INT 21h Handler  That this is at
;;  FDC8:40F8 in this particular configuration is the one piece of
    information we re after here, because now we can go and disassemble
;;  rather than trace  at that address  Static unassembly is
    generally easier than dynamic tracing  But let s see the thing
;;  through  to learn exactly how 21/62 is handled

FDC8:40F9 80FC6C        CMP AH,6C
FDC8:40FC 7702          JA  4100

;   Any INT 21h function > 6Ch is an error  ("In DOS 7 0,
;   the upper limit is 72h," writes one tech reviewer )

FDC8:40FE 80FC33        CMP AH,33
FDC8:4101 721B          JB  411B

;;; Any INT 21h function < 33h will be handled at FDC8:411B

FDC8:4103 74A2          JZ  40A7

;;  21 33 is special  it is handled at FDC8:40A7 (in this configuration)

FDC8:4105 80FC64        CMP AH,64
FDC8:4108 7711          JA  411B

;;  Any INT 21h function > 64h will also be handled at FDC8:411B;
;;  seems like 411B is the handler for "normal" DOS calls.

FDC8:410A 74B5          JZ  40C1

;;; 21 64 is another special function  handled here at FDC8:40C1

FDC8:410C 80FC51        CMP AH,51
FDC8:410F 74A4          JZ  40B5
FDC8:4111 80FC62        CMP AH,62
FDC8:4114 749F          JZ  40B5

;;  Finally  DOS sees our 21/62 call and will handle it by jumping to
;;  FDC8:40B5  Notice that the same code also handles calls to 21/51, which
;   makes sense  since the two functions are documented as being identical

FDC8:40B5 1E            PUSH    DS
FDC8:40B6 2E            CS
FDC8:40B7 8E1EE73D      MOV DS,[3DE7]                           CS:3DE7=0116

;   DOS DS  0116h) is stored in a variable kept at CS 3DE7  This is
;   the segment where things like SysVars and SDA live  This value is
;;; also returned from 2F/1203 (see appendix).

FDC8:40B8 8B1E3003      MOV BX,[0330]                           DS:0330=1408

;;; Believe it or not  the previous line is actually the Get PSP function!
;;  We know that DOS keeps the current PSP at SDA+10h  In this
;   configuration  21/5D06 (Get SDA) returns 0116:0320  The Get PSP
;;; function just moves the WORD at 0116:0330 into BX  In other words,
;;; 21/62 (and 21/51) just return the WORD from SDA+10h  Duh.

FDC8:40BF 1F            POP DS
```

```
FDC8:40C0 CF            IRET

;;; DOS IRETs back to our code running in DEBUG

1985:0104 C3            RET

;;; This is the RET statement in our DEBUG script

1985:0000 CD20          INT 20
0116:1094 90            NOP

;;; Our script has already returned to DEBUG, which did an INT 20h return
;;; to DOS.  At this point, we start tracing all sorts of things we don't
;;; care about.  If we trace too far, we start to make DEBUG execute
;;; garbage, which can hang the machine

-q
```

The most noticeable feature of the INT 21h trace in Figure 6-3 is the way that DOS extensions such as SMARTDRV and MSCDEX become indistinguishable from DOS itself. If a non-Microsoft DOS extension such as Novell NetWare or Stacker had been running, they too would have appeared in the INT 21h chain looking not a bit different from any of the Microsoft-provided software in the chain. The walk through the INT 21h chain in Figure 6-3 thus presents an excellent illustration of what DOS really is.

Unassembling the Get/Set PSP Functions

As you can see, under normal circumstances with a few TSRs loaded, we have to wade through a lot just to get to the single piece of code that actually performs the DOS Get PSP function. It should now be clear why INT 21h is referred to as a "chain." As you'll see after the INT 21h call returns, typically much longer than the INT 21h chain. Given the overhead of INT 21h on a typical machine, programmers might even consider writing their own Get PSP calls to bypass this long interrupt chain. Seeing how DOS implements Get PSP when it eventually gets there will also see how to implement your own.

```
// uses get_sda() from GETSDA.C (Listing 3-4a)
WORD my_get_psp(void)
{
    static WORD far *psp_ptr = (WORD far *) 0;
    if (! psp_ptr)                  // one-time init
        psp_ptr = (WORD far *) (get_sda() + 0x10);
    return *psp_ptr;
}
```

Of course, this would not work if any TSRs or drivers that might actually need to see and respond to DOS Get PSP calls.

Having already seen the code that handles the Get PSP function (INT 21h AH=51h and 62h), we might as well also examine the code for Set PSP, shown in Figure 6-4, though we can guess what it's going to look like. We see later in Figure 6-7 where the 4039h address comes from.

Figure 6-4: Implementation of INT 21h AH=50h (Set PSP) in MS-DOS 6.0

```
-u fdc8 40a9
FDC8:40A9 1E            PUSH    DS              ; save caller's DS
FDC8:40AA 2E            CS
FDC8:40AB 8E1EE73D      MOV DS,[3DE7]           ; switch to DOS DS
FDC8:40AF 891E3003      MOV [0330],BX           ; put caller's BX into CURR_PSP
FDC8:40B3 1F            POP DS                  ; restore caller's DS
FDC8:40B4 CF            IRET                    ; done!
```

Another way to see the Get and Set PSP functions just manipulate this word at offset 330h in the DOS data segment (offset 10h in the SDA). This provides a small taste of how DOS internally uses such undocumented data structures as SysVars and the SDA. Thus

```
void my_set_psp(WORD psp)
{
    static WORD far *psp_ptr = (WORD far *) 0;
    if (! psp_ptr)                      // one-time init
        psp_ptr = (WORD far *) (get_sda() + 0x10);
    *psp_ptr = psp;
}
```

is a typical method as an example of what DOS itself does. Calling this function instead of INT 21 AH=50h is safer because it bypasses NDX and other TSRs that need to see Set PSP calls.

Unassembling INT 21h AH=33h

A glance toward the end of the DEBUG output in Figure 6-3 shows that MS-DOS special cases a handful of the functions (33h, 34h, 50h, 62h) that are not shown in Figure 6-3. 50h, 62h. These functions are similar to the undocumented DOS functions listed in Table 6-1. While we're still not quite at a position to discuss what these functions do differently from all other DOS functions, we do at any rate now have a list of places that we can unassemble. Recall that this was our goal in tracing through DOS.

For example, INT 21h AH=33h is an omnibus function for a miscellaneous set of subfunctions relating to Ctrl-Break checking, the boot drive, and the DOS version. For example, setting BREAK=ON ends up calling INT 21h AX=3301h with DL=1. In the assembly-language code at FDC8:4DA7, handles this function:

```
FDC8:4DFE 80FC33        CMP AH,33
FDC8:4101 7218          JB  411B
FDC8:4103 74A2          JZ  4DA7
```

We've also annotated the Ctrl-Break flag in the DEBUG listing. Using DEBUG or any other DOS debugger, you can add this to the comments in Figures 6-3 and 6-5, which has also been examined slightly.

Figure 6-5. Implementation of INT 21h AH=33h in MS-DOS 6.0

```
C:\UNDOC2\CHAP6>debug
-u 4da7 4e52
FDC8:4DA7 EBA9          JMP 4052
-u 4052 4e52
FDC8:4052 3C06          CMP AL,06       ; functions 3300h through 3306h
FDC8:4054 7603          JBE 4059
FDC8:4056 B0FF          MOV AL,FF       ; error: subfunction number too high
FDC8:4058 CF            IRET
FDC8:4059 1E            PUSH    DS      ; save caller's DS
FDC8:405A 2E            CS:
FDC8:405B 8E1EE750      MOV DS,[50E7]   ; switch to DOS's DS, hmm, not truly
FDC8:405F 50            PUSH    AX      ;     reentrant after all!
FDC8:4060 56            PUSH    SI
FDC8:4061 BE3703        MOV SI,0337     ; offset of break flag:  SDA+17h
FDC8:4064 32E4          XOR AH,AH       ; see if subfunct 0
FDC8:4066 0BC0          OR  AX,AX
FDC8:4068 7504          JNZ 406E
FDC8:406A 8A14          MOV DL,[SI]     ; 21/3300 -- get break flag
FDC8:406C EB35          JMP 40A3
FDC8:406E 48            DEC AX          ; see if subfunct 1
FDC8:406F 7507          JNZ 4078
FDC8:4071 80E201        AND DL,01
FDC8:4074 8814          MOV [SI],DL     ; 21/3301    set break flag
FDC8:4076 EB2B          JMP 40A3
FDC8:4078 48            DEC AX          ; see if subfunct 2
FDC8:4079 7507          JNZ 4082
```

```
FDC8.407B 80E201        AND DL,01
FDC8.407E 8614          XCHG DL,[SI]    , 21/3302 (UNDOC)    get/set brk flg
FDC8 4080 EB21          JMP 40A3        ,   as single atomic operation  XCHG
FDC8:4082 3D0300        CMP AX,0003 , see if subfnc 5 (already subtracted 2)
FDC8 4085 7506          JNZ 408D
FDC8 4087 8A166900      MOV DL,[0069]   ; 21/3305 -- get startup drive
FDC8 4088 EB16          JMP 40A3
FDC8 408D 3D0400        CMP AX,0004 , see if subfnc 6 (already subtracted 2)
FDC8 4090 7511          JNZ 40A3
FDC8 4092 BB0600        MOV BX,0006     , 21/3306 -- MS-DOS version 6.0
FDC8:4095 B200          MOV DL,00
FDC8 4097 32F6          XOR DH,DH
FDC8.4099 803E111200    CMP BYTE PTR [1211],00  , is DOS=HIGH?
FDC8 409E 7403          JZ  40A3
FDC8 40A0 80CE10        OR  DH,10       ; DOSINHMA flag
FDC8 40A3 5E            POP SI          , done  restore caller's regs
FDC8:40A4 58            POP AX
FDC8 40A5 1F            POP DS
FDC8.40A6 CF            IRET            ; return to caller
```

In addition to showing how DOS happens to handle function 33h, the code in Figure 6-5 also provides many snippets of information that can be used to understand the disassembly listing of other parts of MS-DOS. For example, Microsoft documents INT 21h AX=3306h as returning the DOSINHMA flag, and the last section of Figure 6-5 shows DOS using the byte at DOS DS:[211Bh] to set DH. The clause "DOS DS:" is used to point to the DOS DATA segment. It's not important by itself, but it's a useful clue to help you understand other parts of the code. Now we know that DOS DS:[121Bh] is not just a byte, but the byte for DOSINHMA flag.

Similarly, functions 3300h and 3301h can be used to get and set the Ctrl-C flag. Figure 6-5 shows these functions manipulating the word at offset 033Fh in the DOS data segment; this byte must then be the Ctrl-C flag. Figure 6-7 shows how DOS uses this flag. Finally, Microsoft documents INT 21h AX=3305h as returning the startup drive in DL, and the code in Figure 6-5 shows DOS setting DL from [0069]. Characters elsewhere in the code show that [0069] is a variable that we'll translate this to START_UP_DRIVE.

Examining the Low Memory Stub for DOS=HIGH

Another interesting feature of Figure 6-5 is the location that DOS uses as a temporary stack when DOS=HIGH. Because A20 is disabled, the processor's A20 address line forces memory above one megabyte to "wrap around" to zero, as in earlier processors. Inside A20=off, DOS can't use the stack at 70:0 because it would wrap around to 0050:0. Since DOS=HIGH has A20 off, DOS must first enable A20 before it can reach its own HMA variables and data. But DOS's code is relocatable, so how can it know A20's address? The first place we'll look is the code that keeps track of how to set A20: DOS=HIGH. Earlier, Figure 6-3 showed that this was located at 0116:118E. Figure 6-6 shows what this function actually does.

Figure 6-6: DOS Function Called When DOS=HIGH But A20 Is Off

```
u 116 118e
0116 118E 53            PUSH    BX
0116 118F 50            PUSH    AX
0116:1190 8CD0          MOV     AX,SS
0116.1192 2E            CS
0116 1193 A33810        MOV     [1038],AX
0116 1196 2E            CS:
0116 1197 89263810      MOV     [1038],SP       , save caller's stack
0116.119B 8CC8          MOV     AX,CS           , switch to a DOS stack, hmm, not
0116 119D 8ED0          MOV     SS,AX           ,    reentrant at all if A20 off
0116 119F BCA007        MOV     SP,07A0         , SDA+480h=end of Crit Err Stack
0116 11A2 B405          MOV     AH,05           , XMS func 5 = Local Enable A20
```

```
0116 11A4 2E            CS
0116 11A5 FF1E6311      CALL    FAR [1163]  ; XMS address from 2F/4310
0116 11A9 08C0          OR      AX,AX
0116 11AB 740F          JZ      11BC        ; failed: can't turn A20 on!!

;;; okay
0116 11AD 2E            CS:
0116 11AE A1861D        MOV AX,[1D86]
0116 11B1 8ED0          MOV SS,AX
0116:11B3 2E            CS:
0116 11B4 8B268810      MOV SP,[1088]   , switch back to caller's stack
0116:11B8 58            POP AX
0116 11B9 5B            POP BX
0116 11BA EBCB          JMP 1187  , jump back into normal code (fig  6-3)
                                  ; as if A20 had been enabled all along

;;; fail
0116 11BC B40F          MOV AH,0F       , come here if couldn't enable A20
0116:11BE CD10          INT 10          ; get video mode
0116 11C0 3C07          CMP AL,07
0116:11C2 7406          JZ  11CA
0116:11C4 32E4          XOR AH,AH
0116 11C6 B002          MOV AL,02       , set normal text mode
0116 11C8 CD10          INT 10
0116 11CA B405          MOV AH,05
0116 11CC 32C0          XOR AL,AL       ; set display page 0
0116 11CE CD10          INT 10
0116 11D0 BEB812        MOV SI,1288     , 1288 -> "\nA20 Hardware Error\n$"
0116:11D3 0E            PUSH    CS
0116:11D4 1F            POP DS
0116:11D5 FC            CLD
0116 11D6 AC            LODSB
0116 11D7 3C24          CMP AL,24       ; look for '$'
0116 11D9 7409          JZ  11E4
0116 11DB B40E          MOV AH,0E       , write in TTY mode (use BIOS
0116 11DD BB0700        MOV BX,0007     ,    since can't make DOS calls
0116 11E0 CD10          INT 10          ;    here!)
0116 11E2 EBF2          JMP 11D6
0116:11E4 FB            STI
0116 11E5 EBFD          JMP 11E4        ; tight little loop (INTs on)

d 116 12b8
0116 12B0                               0D 0A 41 32 30 20 48 61           A20 Ha
0116 12C0  72 64 77 61 72 65 20 45-72 72 6F 72 0D 0A 24 36  rdware Error. $6
```

Notice in the assembly that DOS leaves the A20 line on. This reduces the overhead of keeping the DOS code in the HMA. DOS probably doesn't have to call the new memory stub in Figure 6-6 very often.

Data stored in DOS or the HMA are guarded with this low-memory stub. It brings up an interesting question: What about *data* in the HMA? MS-DOS doesn't put external data structures such as the Current Directory Structure, CDS and System File Tables, SFTs in the HMA because this would break the many third-party applications that peek and poke these ostensibly internal structures and that wouldn't know to first ensure that A20 is enabled. However, DOS does keep its BUFFERS in the HMA. If a program issues an INT 21 BUFFERS call (Chapter 8, see Listing 8-8) accesses the DOS sector buffers, or if some internal access to DOS has BUFFERHIGH or LASTDRIVEHIGH statements that use HMA, DOS does not guarantee A20. But since these are the only two ways we've seen so far that DOS can wind up in the HMA, perhaps a program that accesses data in the HMA merely needs to preface that access with a call to DOS call DOS will take care of checking the A20 state and, if necessary, calling XMS function 3 to enable A20. But any TSR could turn it off. How frequently should programs that access the HMA check the A20 state? How much of a problem is this? Is the extra few kbytes gained

by putting data in the HMA worth this kind of uncertainty. ("Ouch! This makes my head hurt," says one of the tech reviewers.)

Examining the INT 21h Dispatch Function

Of all the addresses we found through tracing, the INT 21h call is the most important. It's start of DOS's INT 21h handler, seen in Figure 6-3 at FDC8:40F8. This is really the piece of information we wanted all along. To see exactly what happens during an INT 21h call, we can now disassemble at this address. By tracing in INT 21h AH=62h, we only saw those snippets that bypass to get executed when calling the Get PSP function. We can now look at the entire function. (See Figure 6-7.) The DOS INT 21h handler also time-wise used SYMDEB and added some labels as well as comments. In Microsoft's source code, this all important function located in MSDISP.ASM is called COMMAND.

Figure 6-7: MS DOS 6.0 INT 21h Dispatch Function

```
-u fdc8:40f8
FDC8.40F8 FA              CLI                     ; disable interrupts
FDC8.40F9 80FC6C          CMP     AH,6C
FDC8.40FC 77D2            JA      4080            ; invalid function number

; step 1
FDC8:40FE 80FC33          CMP     AH,33
FDC8:4101 7218            JB      411B            ; normal DOS function
FDC8:4103 74A2            JZ      40A7            ; do 21/33 (fig. 6-5)
FDC8:4105 80FC64          CMP     AH,64
FDC8:4108 7711            JA      411B            ; normal DOS function
FDC8:410A 7485            JZ      4091            ; do 21/64
FDC8:410C 80FC51          CMP     AH,51
FDC8:410F 74A4            JZ      40B5            ; do Get PSP
FDC8:4111 80FC62          CMP     AH,62
FDC8:4114 749F            JZ      40B5            ; do Get PSP (51=62)
FDC8:4116 80FC50          CMP     AH,50
FDC8:4119 748E            JZ      40A9            ; do Set PSP (fig. 6-4)

normal_DOS
; step 2
; caller's flags, CS, and IP of course already pushed on the stack by INT
FDC8:411B 06              PUSH    ES      ; 10h   ; Save regs on caller's stack
FDC8:411C 1E              PUSH    DS      ; 0Eh   ; The order is important, as
FDC8:411D 55              PUSH    BP      ; 0Ch   ; later on different INT 21h
FDC8:411E 57              PUSH    DI      ; 0Ah   ; functions will access the
FDC8:411F 56              PUSH    SI      ; 08h   ; caller's original registers
FDC8:4120 52              PUSH    DX      ; 06h   ; by treating this stack frame
FDC8:4121 51              PUSH    CX      ; 04h   ; as a structure. See 21/1218
FDC8:4122 53              PUSH    BX      ; 02h   ; for example, caller's BX
FDC8:4123 50              PUSH    AX      ; 00h   ; is at offset 2, ES at 10h

; step 3
FDC8:4124 8CC8            MOV     AX,DS
FDC8:4126 2E8E1EE73D      MOV     DS,CS:[3DE7]        ; get DOS DS
FDC8:412B A3EC05          MOV     [05EC],AX           ; save caller's DS
FDC8:412E 891EEA05        MOV     [05EA],BX           ; save caller's BX
FDC8:4132 A18405          MOV     AX,[0584]   ; SDA+264h = ptr to stack frame
FDC8:4135 A3F205          MOV     [05F2],AX   ;    containing user registers
FDC8:4138 A18605          MOV     AX,[0586]   ;    on INT 21h
FDC8:413B A3F005          MOV     [05F0],AX

; step 4
FDC8:413E 33C0            XOR     AX,AX               ; set AX=0
FDC8:4140 A27205          MOV     [0572],AL
FDC8:4143 F606303001      TEST    Byte Ptr [0330],01 ; Is Win3 Enh running?
FDC8:4148 7503            JNZ     414D
```

```
; for swing time only if Windows 3 Enhanced mode not running!
FDC8:414A A33E03          MOV     [033E],AX           ; set machine ID to zero

; step 5
FDC8:414D FE062103        INC     Byte Ptr [0321]     ; increment InDOS flag

; step 6
FDC8:4151 89268605        MOV     [0586],SP           ; SDA+264h
FDC8:4155 8C168805        MOV     [0588],SS           ; save current stack ptr
FDC8:4159 A13C03          MOV     AX,[033C]           ; get current PSP
FDC8:415C A33C03          MOV     [033C],AX           ; SDA+1Ch = SHARE, NET PSP
FDC8:415F 8ED8            MOV     DS,AX               ; point DS at caller's PSP
FDC8:4161 5B              POP     AX
FDC8:4162 50              PUSH    AX                  ; get back caller's AX
FDC8:4163 89262E00        MOV     [002E],SP           ; save current stack ptr
FDC8:4167 8C163000        MOV     [0030],SS           ;    in caller's PSP
FDC8:416B 2E8E16E730      MOV     SS,CS:[30E7]
  INT 21h AX 5000h (Server Function Call) jumps to here
                                    ; switch stack to 07A0h-SDA =
FDC8:4170 BCA007          MOV     SP,07A0  ;   SDA+480h=end of Crit Err Stk

; step 7
FDC8:4173 FB              STI                         ; reenable interrupts
FDC8:4174 8CD5            MOV     BX,SS
FDC8:4176 8ED8            MOV     DS,BX               ; point DS at DOS_DS
FDC8:4178 93              XCHG    AX,BX               ; caller's AX into BX
FDC8:4179 33C0            XOR     AX,AX
FDC8:417B 36A2F605        MOV     SS:[05F6],AL        ; extended open off?
FDC8:417F 3681261160D0D8  AND     Word Ptr SS:[6011],D8D0
FDC8:4186 36A25703        MOV     SS:[0357],AL        ; set different vars to 0
FDC8:418A 36A24C03        MOV     SS:[034C],AL
FDC8:418E 36A24A03        MOV     SS:[034A],AL
FDC8:4192 40              INC     AX
FDC8:4193 36A25803        MOV     SS:[0358],AL        ; okay to do INT 28h

; step 8
FDC8:4197 93              XCHG    AX,BX               ; get back caller's AX
FDC8:4198 8AEC            MOV     BL,AH               ; DOS func num into BL
FDC8:419A D1E3            SHL     BX,1     ; make DOS func number into word ofs

; step 9
FDC8:419C FC              CLD
FDC8:419D 0AE4            OR      AH,AH
FDC8:419F 7417            JZ      41B8                ; AH=0 (terminate process)
FDC8:41A1 80FC59          CMP     AH,59
;  if 21 59 (get critical error), bypass code that turns off critical error!
FDC8:41A4 7444            JZ      41EA                ; AH=59h (get extended error)
FDC8:41A6 80FC0C          CMP     AH,0C
FDC8:41A9 7700            JA      41AB                ; AH > 0Ch

INT21_01_THRU_0C
; step 10
FDC8:41AB 36803E200300    CMP     Byte Ptr SS:[0320],00  ; critical error set?
FDC8:41B1 7537            JNZ     41EA     ; if so, stay with crit error stack
FDC8:41B3 BCA00A          MOV     SP,0AA0  ; SDA+780h=end of Char I/O Stack
FDC8:41B6 EB32            JMP     41EA

INT21_00
INT21_ABOVE_0C  ... except (normally) 33h, 50h, 51h, 59h, 62h, 64h
; step 11
FDC8:41B8 36A33A03        MOV     SS:[033A],AX
FDC8:41BC 36C6062303 01   MOV     Byte Ptr SS:[0323],01  ; crit err locus
FDC8:41C2 36C6062003 00   MOV     Byte Ptr SS:[0320],00  ; turn off crit error
FDC8:41C8 36C6062203FF    MOV     Byte Ptr SS:[0322],FF  ; crit err drive#
```

```
; Windows Enhanced mode patches next four lines into a far call
FDC8:41CE 50              PUSH   AX
FDC8:41CF B482            MOV    AH,82
FDC8:41D1 CD2A            INT    2A                    ; End crit section
FDC8:41D3 58              POP    AX

FDC8:41D4 36C606580300    MOV    Byte Ptr SS [0358],00   ; no INT 28h
FDC8:41DA BC2009          MOV    SP,0920        ; SDA+600h = end of Disk Stack
FDC8:41DD 36F6063703FF    TEST   Byte Ptr SS [0337],FF , SDA+17h break flag
FDC8:41E3 7405            JZ     41EA
FDC8:41E5 50              PUSH   AX                      , BREAK=ON, so
FDC8:41E6 E8964E          CALL   907F                    ; check ctrl-break
FDC8:41E9 58              POP    AX

; step 12
;;; Next four lines are the key  call through dispatch table
;;; BX holds caller's INT 21h function number SHL 1  word offset
FDC8:41EA 2E889F9E3E      MOV    BX,CS [BX+3E9E]  , get func handler addr
FDC8:41EF 36871EEA05      XCHG   BX,SS [05EA]     , move func ptr into var
FDC8:41F4 368E1EEC05      MOV    DS,SS [05EC]  , switch to caller's saved DS
FDC8:41F9 36FF16EA05      CALL   SS:[05EA]        , call func handler addr
;;; We've just called the DOS function for the specific DOS function in AH

; step 13
;;; Now into cleanup preparatory to returning to caller
FDC8:41FE 3680268600FB    AND    Byte Ptr SS [0086],FB
FDC8:4204 FA              CLI
FDC8:4205 2E8E1EE730      MOV    DS,CS [30E7]     , switch back to DOS DS
FDC8:420A 803E850000      CMP    Byte Ptr [0085],00
FDC8:420F 7527            JNZ    4238
FDC8:4211 FE0E2103        DEC    Byte Ptr [0321]         , decrement InDOS
FDC8:4215 8E168605        MOV    SS,[0586]        , switch back to caller's
FDC8:4219 8B268405        MOV    SP,[0584]        ,   stack
FDC8:421D 8BEC            MOV    BP,SP
FDC8:421F 884600          MOV    [BP+00],AL
FDC8:4222 A1F205          MOV    AX,[05F2]
FDC8:4225 A38405          MOV    [0584],AX        ; caller's SP
FDC8:4228 A1F005          MOV    AX,[05F0]
FDC8:422B A38605          MOV    [0586],AX        ; caller's SS
FDC8:422E 58              POP    AX               ; put back caller's
FDC8:422F 5B              POP    BX               ; registers, including
FDC8:4230 59              POP    CX               ; any changes the DOS
FDC8:4231 5A              POP    DX               ; function made to them
FDC8:4232 5E              POP    SI
FDC8:4233 5F              POP    DI
FDC8:4234 5D              POP    BP
FDC8:4235 1F              POP    DS
FDC8:4236 07              POP    ES
FDC8:4237 CF              IRET
```

The dispatch table [illegible] is the heart of DOS. It is executed every time a program issues an INT 21 [illegible] the dispatch table [illegible] DOS equivalent of the function vector table in UNIX, which is [illegible] and books such as Bach's *Design of the UNIX Operating System* (pp. 165–168) and Andleigh's *UNIX System Programming* (pp. 21–23). The discussions centered on these and other UNIX books provide valuable background for understanding the INT 21h dispatch code. However, [illegible] UNIX [illegible] a crucial separation between applications and the operating system. The discussion of system calls [illegible] the transition from user mode to system mode. As we will see later, [illegible] like those in DOS. Although DOS extenders such as Windows/386 maintain a separation between the application and DOS in protected mode, DOS running in real mode does not. This is an important [illegible] DOS usually switches from the application's stack to its own. This important aspect of DOS will be discussed in detail below.

Near the top of the function commented "step 1" you see how DOS picks off a handful of special functions (33h, 64h, 51, 62h, and 50h). These, of course, are none other than what we've been calling the reentrant DOS functions. Here, reentrancy simply means that while the above code is executing (after it has passed the critical CLI and before it has executed the closing IRET), it could be interrupted by an interrupt handler, and the interrupt handler could call one of these five functions. These five functions are reentrant simply in the sense that DOS handles them without switching stacks and incrementing the InDOS flag. Thus an interrupt handler can call these functions, even if the InDOS or critical error flag is set.

In a large sense, of course, these functions aren't really reentrant, given the way that, for example, the Set PSP function writes to a global variable (see Figure 6-4). MS-DOS's extensive reliance on global variables makes it completely non-reentrant. Furthermore, if DOS=HIGH and the A20 line is off, DOS, as figure 6-6 showed, has to switch stacks. But in any case, it should now be clear why we noted INT 21, AH=62 (or traced with DEBUG to) and not say, INT 21h AH=52h, DOS handles the latter function only after switching stacks and incrementing InDOS.

Next, step 2 in the INT 21 dispatch code pushes the caller's registers on to the caller's stack. The caller's, of course, is simply whatever program issued the INT 21h call. This can be slightly disorienting because it's easy to get used to thinking about INT 21h from the caller's perspective, and now we're looking at it from DOS's point of view. These pushed registers form a structure that many DOS functions refer to. (Undocumented INT 21h, AX=1218h, Get Caller's Registers, see appendix) returns a pointer to this structure.

At step 3 in figure 6-7, DOS saves away the caller's DS and BX again and switches from the caller's DS to its own DS. DOS keeps DS in a variable accessible through DOS's CS. It is also available on call to INT 21, AX=1203h; see get_dos_ds in Listing 6-2. Note that even though DOS is loaded high, the DOS code in the HMA, the data segment is still in low memory. This is necessary because many existing DOS programs rely on the ability to reach DOS internal data structures and would break if Microsoft tried to relocate the DOS data segment. Microsoft has to introduce improvements such as HIMEM.SYS without breaking existing applications.

The next thing that step 3 (in the code) does is step 4—check a variable at 1030h to see whether Windows 3.x Enhanced mode or Windows/386 2.x is running. Since most of us think of Windows as something that runs "on top of" DOS, it's a bit disconcerting at first to learn that DOS 5.0 and higher is aware of Windows. As discussed in Chapter 1, however, this part of the intricate DOS-Windows communication scheme dates to undocumented functionality. In its INT 21h handler, MSDOS.SYS monitors (for AX=1605h Windows start broadcasts and AX=1606h exit broadcasts), the code for AX=1605h sets the variable at 1030h, not at the byte at 1031h, and the code for AX=1606h clears it. DOS variable thus serves as a kind of Windows flag. It's important to underline that this variable means only DOS doesn't care one way or the other about Standard mode.

If Windows Enhanced mode (/3) is running, then DOS zeroes out a variable at 0331h (SDA+1). The word used by DOS is the machine ID. If Windows Enhanced mode is running, the DOSMGR VxD, as explained in Chapter 1, has smacked a virtual machine ID in here. DOS uses this VM ID to manage SFTs.

Next, step 5—the code increments the InDOS flag, which is simply a variable at 0321h (SDA+1) in the DOS data segment. The most recently undocumented function INT 21h AH=34h (Get InDOS Flag Address) returns a pointer to this variable.

The InDOS flag has been set, so we're now "in DOS." Of course, we were in DOS before, but the significance of this spot is that DOS is about to switch stacks. Switching stacks requires a guard or semaphore, which the InDOS flag. Notice, however, that while DOS increments the InDOS flag, it does not check it before proceeding. Thus InDOS is not a true semaphore. If the processor is interrupted in the middle of this code (or rather, a little further on when DOS reenables interrupts with an STI instruction), the code can be reentered.

In other words, DOS does nothing to enforce its requirement that only one caller at a time execute inside the INT 21h code. Obeying the InDOS flag is merely a convention. But it is vital that programs do observe this convention. Because making an INT 21h call when InDOS is set will almost always cause problems—or something. DOS relies on many global variables. If, for example, DOS were working with a particular hard disk cluster (service in INT 21h) for a FCB call and an interrupt handler that ignored the InDOS flag made a disk I/O call to DOS before DOS had finished with the first one, DOS would be mistaken if it used the second caller's cluster to satisfy the first caller's request. Global variables do not work like a last-in first-out stack. It is vital that interrupt handlers check the InDOS status flag before issuing INT 21h calls. Now you see why Microsoft is so long to document InDOS and the INT 21h AH=34h function that returns a pointer to it.

Ignoring InDOS can cause another problem. Because the code at step 5 in Figure 6-7 increments InDOS (entering DOS means that InDOS will take on a value of two or greater). This is bad because the internal DOS function that checks for Ctrl-C only does so when CALL Buffer IN DOS, OEM Functions InDOS is 2 or greater. DOS won't check Ctrl-C except BREAK=ON.

There's a problem with when DOS can be safely restarted. If the entire DOS state—including all three DOS stacks—is saved and restored by each caller, and if each such caller observes the DOS critical sections by bracketing INT 21h. The SDA ISR we mapped out forward in Chapter 9 is an approximation of this method. (We give it an approximation because the SDA does not include the entire DOS state.)

Returning to step 6 in Figure 6-7, you can see the beginnings of the stack switching code. How does DOS switch away from the user's stack to one of its own? First, it saves away the caller's current SS:SP. Next, DOS gets the current PSP (at 0330h or SDA+10h) and uses it to save the caller's SS:SP at offset 2Eh in the caller's PSP. Finally, DOS sets SS:SP to a DOS stack. Depending on the DOS function number, DOS may switch again to a different DOS stack.

What is the purpose of stack switching? Why not just use the caller's stack? Wouldn't that make DOS much more reentrant? Yes, it would. As you're making an INT 21h call, it reads uses 18h bytes on the caller's stack (see Table 6-2). If the caller could be relied on to provide a large enough stack, DOS could execute with the caller's stack. Unfortunately, DOS has to accommodate programs with unknown stack sizes. This complicates DOS's housekeeping and helps make DOS reentrant.

At the several of steps 6 where DOS points SP at the Critical Error stack is a location called ReEnter in the source code. (Search for code mentioned INT 21h, AX=5D00h, Server Function Call.) Jumps to this location switch back to the INT 21h dispatcher. If a network software program hooks this call, it can be used by one machine to redirect an INT 21h call to another machine—or perhaps to another Windows virtual machine.

Skipping over a bunch of the code in step 7, which zeroes out several variables in the DOS data segment, we come to step 8, where the code takes the caller's AH (with the critical DOS function number) and turns it into a word offset in AX. This will be important later on.

Next, step 9 of DOS examines the function number in AH. If AH=59h, Get Extended Error Info is being called. DOS proceeds directly to step 12, where the code for function 59h will be called. It stays on the Critical Error Stack, bypassing more stack switching code in steps 10 and 11, and bypassing code that would create information pertaining to any pending Critical Error.

If one of the GET/SET based character I/O functions (INT 21h, AH=1 through AH=0Ch) is being called, DOS step 10 points SP at 0A40h, which is on top of the character I/O stack located in the Swappable Data Area (see appendix). However, if there's a pending critical error, DOS stays with the Critical Error stack that was set up earlier. This is not surprising, since Microsoft documents these functions *"As DOS Is Assumed to Be Reentrant"* as callable from a critical error handler. Notice that DOS does not turn off critical error information for functions 1 through 0Ch. As you can see, much of the core DOS code accommodates critical errors.

...ally if the DOS function number is 0 Terminate Program or anything greater than 0Ch but not 59h ...one of the special functions that were picked off earlier in step 1 and which DOS should process ...the caller's stack DOS step 11 switches to the disk stack Thus, there are three DOS stacks

- Critical ... stack used for function 59h and for functions 1 through 0Ch when a ... is pending and used temporarily for any DOS function call if DOS-HIGH but A20 is off
- Character I/O Stack, used for functions 1 through 0Ch in the absence of a critical error
- Disk ... used for everything else Calling any of the special functions with the INT 21h AX=5D00h ... function call also ends up using this stack Though not practical ... the special functions via 21=5D00h crashes the machine

...the ... of the functions running on the disk stack the code ... step 11 carries out a number of tasks ... critical sections or ... undocumented INT 2Ah AH=82h to find any critical sections ... ... Ctrl C Check flag at SDA+17h In Figure 6-5 you saw the code for INT 21h AX=5D00h that sets this flag when ... used ... BREAK ON Now you can see when DOS ... this flag To find BREAK ON check ... flag at SDA+17h is now zero DOS calls a ... ... 90 ... to check Ctrl C for the functions that come through here Otherwise DOS ... Ctrl C for functions 1 through 0Ch As noted earlier the DOS internal ... to check Ctrl C will only do so if INDOS = 1

... ... to INT 2Ah AH=82h Normally the INT 2Ah handler in DOS does an immediate IRET ... no operation However other programs can take over INT 2Ah and/or patch DOS ... Windows Enhanced mode in particular uses INT 2Ah critical sections because it runs preemptively ... DOS ... to support a simple copy of MS DOS Because the InDOS flag is ... per VM each DOS has gets its own copy It cannot be used to control access to DOS ... by ... VMs Now you know why the InDOS flag is ... as different VMs could be in different parts of DOS at the same time What different parts Different critical sections can be set and ... INT 2Ah AH=80h and 81h ... operations DOS's call to INT 2Ah AH=82h is a signal ... ... DOS ... such as Windows or networking software can restart any task VM ... ... because it was waiting for a critical section For additional information on ... ... see Chapter 1 and Chapter 9 ... RBIN(C) Ch 9 Listing 9-19 Also see Microsoft's *MS-DOS ... Reference* ... 41 ... which briefly discusses critical sections in the context of the MRC specification

As discussed ... Chapter 6 the DOSMGR.VxD ... Windows Enhanced mode patches this INT 2Ah AH=82h ... INT 2Ah dispatch routine ... into a far call into Windows When Windows exits ... hopefully ... back the original code

... ... critical sections which do dominate the DOS ... ... sight of the main goal which is that a program wants to call a DOS ... A ... piece of software DOS accomplishes this main goal in only a few lines while ... ... and some ... back ... seconds

... ... to the ... stack save the caller's reg ... and set up, step 12 in Figure 6-7 ... ... important Recall that step 8 moved the function number in AH into AX ... ... DOS ... ... value as an offset into an array of function pointers, ... DOS ... Here ... ... CS:191 ... that for example the address for DOS ... CS:3E91 ... ... is at CS:3E90 function 2's address is at CS:3EA0 function 2's address is at CS:3EA2, and so on Now ... ... loads two byte words ... ... pointers you can reset to hook individual DOS functions All handlers must be located in a single segment here ... 8h We come back to this ... of ... ... pointers momentarily It is very important to us In any case, having retrieved the

address of the handler for the DOS function being called. DOS calls the handler. Ta-da! The function the user wanted has now been called.

In step 13, instead of the appropriate handler for the DOS function, DOS decrements the InDOS flag, switches stacks, pops back the caller's stack, and pops back the caller's registers from the register image created on the stack back in step 2. As you'll see in a moment, the handler for the specific DOS function probably modifies the register image. Finally, DOS returns to the caller with an IRET. Since IRET pops the flags off the stack, the specific DOS functions have to set or clear the carry flag by modifying the image that the processor pushed on the stack as part of the original INT (see the comment to step 2).

Seeing the DOS dispatch code in Figure 6-7 should now make clear why a DEBUG trace through an INT 21h AH=62h call works, but tracing, for example, through a call to INT 21h AH=52h would not. A call to AH=52h would involve switching stacks, messing with global variables in the DOS data segment, and so on. DEBUG, instead of DOS, sees what would end up instead of tracing through one of the DOS calls that DEBUG would be stuck up to display your information. A complete mess! One alternative, of course, is to use a debugger that bypasses DOS, such as SoftICE or Tom Patterson's SERMON from the first edition of *Undocumented DOS*, which, however, did not support tracing through INT instructions.

Examining the INT 21h Dispatch Table

We really don't need to trace through INT 21h any more. We now have the address of COMMAND's The One True INT 21h Handler, and the address of the local pointer array called Dispatch in the DOS source code. So let's just disassemble it ourselves rather than trace under pressure, so to speak.

To find the code that handles each specific DOS function, we need to do a little debugger work that dumps out the Dispatch table, which you can see from step 12 in Figure 6-7 is located at F0C8:3E9E. The code shown here uses Debug's convenient dump, Load, SYMDEB's dissassemble command:

```
-dw fdc8:3e9e
FDC8:3E9E  A1F6 54E0 54E9 559F 55BC 55C2 541C 5448
FDC8:3EAE  510A 5216 5220 55D6 55E0 4DA1 4C78 5CCC
FDC8:3EBE  5688 5D0F 5E73 5625 5DCB 5D0D 5DB1 56F9
FDC8:3ECE  440D 4C73 4C68 4D2D 4D2F 4400 4400 4D71
FDC8:3EDE  440D 5DD5 5D0A 5639 560D 4C9A 4EB6 5DC6
FDC8:3EEE  5DC1 4D22 4839 4856 4876 4887 4A46 4C54
FDC8:3EFE  4A1C A19A 4D73 4D52 4D59 4C8A 4C2B 4CC9
FDC8:3F0E  4A4D 60E1 6029 6065 AFE6 AF0F A72A AB39
;  ,  etc
```

You can double-check your access code by looking for a known function. Let's see what the table shows for function 62h (although we know it usually gets picked off in step 1 of Figure 6-7 only coming through this table for a function which event of an INT 21h AX=3000h request function call of AH=62h):

```
-dw fdc8:(3e9e+62*2
FDC8:3F62  40B5

-u fdc8:40b5
FDC8:40B5 1E              PUSH    DS
FDC8:40B6 2E8E1EE730      MOV     DS,CS:[30E7]
FDC8:40BB 8B1E4003        MOV     BX,[0340]
FDC8:40BF 1F              POP     DS
FDC8:40C0 CF              IRET
```

That's it! Now we have the DOS dispatch table and can examine at will the code for any DOS function you're interested in.

Examination of this table and others like it is made easier with a short C program, FTAB.C, shown in Listing 6-4. FTAB can display tables of bytes (1), words (2), or dwords (4).

Listing 6-4: FTAB.C

```
/* FTAB.C */

#include <stdlib.h>
#include <stdio.h>
#include <dos.h>

typedef unsigned char BYTE;
typedef unsigned short WORD;
typedef unsigned long DWORD;

void fail(const char *s) { puts(s); exit(1); }

main(int argc, char *argv[])
{
    char *prefix;
    void far *tab;
    BYTE far *btab;
    WORD far *wtab;
    DWORD far *dtab;
    WORD seg, ofs;
    int num_func, size, i;

    if (argc < 4)
        fail("usage: ftab <seg ofs> <num_func | *> [prefix] [size]");

    sscanf(argv[1], "%04X:%04X", &seg, &ofs);
    tab = (void far *) MK_FP(seg, ofs);

    if (argv[2][0] == '*')
    {
        num_func = *((BYTE far *) tab);      /* first BYTE is #func */
        tab = ((BYTE far *) tab + 1);        /* then array of WORDs */
    }
    else
        sscanf(argv[2], "%04X", &num_func);

    prefix = (argc > 3) ? argv[3] : "func";
    size = (argc > 4) ? atoi(argv[4]) : 2;  /* default to WORD table */

    switch (size)
    {
        case 1:
            for (i=0, btab=(BYTE far *)tab; i<num_func; i++, btab++)
                printf("%02X\t%s_%02X\n",
                    *btab, prefix, i);
            break;
        case 2:
            for (i=0, wtab=(WORD far *)tab; i<num_func; i++, wtab++)
                printf("%04X:%04X\t%s_%02X\n",
                    seg, *wtab, prefix, i);
            break;
        case 4:
            for (i=0, dtab=(DWORD far *)tab; i<num_func; i++, dtab++)
                printf("%Fp\t%s_%02X\n",
                    *dtab, prefix, i);
            break;
        default:
            fail("size only 1 (byte), 2 (word), 4 (dword)");
    }

    return 0;
}
```

To generate a list of the 6Ah through 6Ch different DOS INT 21h functions (not including 72h, not 6Ch is the highest function number in the DOS 7.0 component of Windows 95, says one tech reviewer), run FTAB executable at FDC8:3E9E. Figure 6-8 shows sample output from FTAB.

Figure 6-8: The INT 21h Dispatch Table Displayed by FTAB

```
C:\UNDOC2\CHAP6>ftab fdc8 3e9e 60 int21 2
FDC8:A1F6    int21_00
FDC8:54E0    int21_01
FDC8:54E9    int21_02
FDC8:559F    int21_03
; ...
FDC8:4C9A    int21_25
; ...
FDC8:4D59    int21_34
FDC8:4C8A    int21_35
; ...
FDC8 AF0F    INT21_3D
FDC8:A72A    INT21_3E
FDC8 A839    INT21_3F
FDC8 A89F    INT21_40
FDC8:BD38    INT21_41
FDC8 ABA4    INT21_42
; ...
FDC8:4DA9    int21_50
FDC8 4DB5    int21_51
FDC8:4D65    int21_52
FDC8:4DD6    int21_53
FDC8 4A41    int21_54
FDC8 4EA5    int21_55
FDC8:BD5E    int21_56
FDC8 A90C    int21_57
FDC8 A448    int21_58
FDC8:4CD0    int21_59
FDC8 B0E9    int21_5A
FDC8 B0D1    int21_5B
FDC8:B2DB    int21_5C
FDC8 A531    int21_5D
FDC8 AA49    int21_5E
FDC8 A9AA    int21_5F
FDC8 AEA8    int21_60
FDC8:44DD    int21_61
FDC8:4DB5    int21_62
; ...  etc
```

A cursory glance at the table's contents will reveal that int21_51 and int21_62 are located at the same address, FDC8:4DB5, as they should be.

Get SysVars and the Caller's Registers

To check that the FTAB output in Figure 6-8 is correct, examine another function that should be simple: INT 21h AH=52h, which returns a far pointer to SysVars in ES:BX. According to the FTAB output, the code for this function (52h) should be at FDC8:4D65, so you can use SYMDEB or DEBUG to disassemble code at that address. Figure 6-9 shows the results.

Figure 6-9: MS-DOS 6.0 Implementation of INT 21h AH=52h (Get SysVars)

```
-u fdc8 4d65
FDC8 4D65 E81AF5          CALL    4282
FDC8:4D68 C7440226000     MOV     Word Ptr [SI+02],0026
FDC8:4D6D 8C5410          MOV     [SI+10],SS
FDC8:4D70 C3              RET
```

In fact, calling Get SysVars in this particular configuration does return 0116:0026, so the hard-wired 0026h code took correct. But what is going on here? How come we don't see SS:0026 being accessed at ES:BX? What are SI+021 and SI+10h? To answer these questions, let's examine the subroutine being called at 4282h:

```
-u 1dc8 4282
FDC8 4282 2E8E1EE73D      MOV     DS,CS:[3DE7]
FDC8,4287 C5368405        LDS     SI,[0584]
FDC8 428B CB              RET
```

CS:3DE7 is initialized to 0 and is used as step 3 in Figure 6-7—the DOS data segment whose value DOS keeps in its code segment. DOS stores the value of DS in its code segment because, when an INT executes, DS points to your data, but CS:xxxx. So this subroutine is first setting itself up to use DOS's DS, just as DOS did at 11:xxxx. Figures 6-3, 6-4, and 6-7 for Get PSP, Set PSP, and the INT 21h dispatch.

The second line loads DS:SI with something at DOS:584h. In step 6 of the INT 21h discussion in Figure 6-7, I said DOS set the thread at DOS:584h to the caller's SS:SP. In other words, DOS:584h contains a pointer to the caller's stack, with all the registers that were pushed onto that stack (step 2 of Figure 6-7) and all control as part of the actual INT instruction. Sure enough, the comment says "3 pointer into DOS 584h at this configuration happens to be SDA+264h, which is the pointer to the stack frame containing the user registers on entry to the INT 21h call."

So, this instruction (DOS 4287) loads DS:SI with a pointer to the caller's pushed register structure. Curious readers who studied steps 2 and 3 of Figure 6-7 will be surprised to learn that the pushed register structure has the format shown in Table 6-2.

Table 6-2: MS-DOS Caller's Register Structure

00h	AX
02h	BX
04h	CX
06h	DX
08h	SI
0Ah	DI
0Ch	BP
0Eh	DS
10h	ES
12h	IP
14h	CS
16h	Flags

In Figure 6-12, the code for function 52h at 11C8:41D6h moves 26h into [SI+2] and DOS's SS into SI+10h. DS:SI points at the caller's register structure, where offset 2 is BX and offset 10h is SS. So this code is actually setting up an image of the caller's ES:BX to DOS:DS:1026—the register values prepared by the various PUSH instructions in the series of PUSHes at the end of step 13 of the INT 21h discussion in Figure 6-7. So this is now INT 21h function 52h returning SysVars in ES:BX. If you want to see how DOS creates SysVars in the first place, you need to disassemble the DOS initialization code. You can learn more from the appendix that lists an external DOS function, INT 2Fh AX=1218h, to get the caller's register structure. It returns a pointer to the structure in DS:SI. This sort of DOS function is discussed at 11C8:4282. In fact, they are one and the same function. DOS offers some of its services through a near function pointer rather than through an INT 21h (or INT 2Fh) call. Within a couple of INT 2Fh AH=12h subfunctions, 4282h does appear as the handler for subfunction 18h.

A Very Brief Glance at File I/O

Next, let's look at a more interesting function. From figure 6-8, the code for INT 21h AH=3Fh "Read File" is supposed to be located at FDC8:A839. The code for this function is too extensive to examine in depth here, so let's just look at the first two lines.

```
-u FDC8:A839
FDC8:A839 BEFD71          MOV     SI,71FD      ; offset of internal Read func
FDC8:A83C E82DFE          CALL    A66C         ; see below
-
```

You know that function 3Fh expects a file handle in BX, and you know that internal file handles are associated with the current PSP. Examining the subroutine called at A66C shows how DOS uses the passed-in file handle:

```
-u FDC8:A66C
FDC8:A66C 2E8E06E73D      MOV     ES,CS:[3DE7]    ; get DOS DS
FDC8:A671 268E063003      MOV     ES,ES:[0330]    ; ES = current PSP
FDC8:A676 263B1E3200      CMP     BX,ES:[0032]    ; PSP[32h] = # max open files
FDC8:A67B 7204            JB      A681
FDC8:A67D B006            MOV     AL,06           ; 6 = invalid handle error
FDC8:A67F F9              STC                     ; set carry flag
FDC8:A680 C3              RET
FDC8:A681 26C43E3400      LES     DI,ES:[0034]    ; PSP[34h] -> file handle tbl
FDC8:A686 03FB            ADD     DI,BX           ; use file handle as offset
FDC8:A688 C3              RET
```

In other words, this subroutine uses the current PSP to convert the passed file handle into a pointer to the caller's SFT (the tables are discussed in Chapter 8). Depending on this pointer, control passes into the System File Table Driver. Once the DOS Read function call has been executed, the buffer specified by the caller will contain the data read from the file. When control returns to the application, the 8088 instruction pointer will point to the next instruction following the INT 21h call. Of course, Read calls can't get back to the application program until the requested disk data is transferred (which can take a long time). This is the whole point of disk caching.

The subfunctions of DOS Xenix calls other than the ones listed for the internal DOS functions of INT 21h AX=1220h (Get Jump Table Address) are supported. You can see from the entry that many DOS functions call one another. For example, INT 21h AX=21h (Read record from FCB) calls INT 21h AX=14h (Sequential read). And the "MOV DS:CS:[3DE7],DS" code that you see many times sounds a lot like INT 21h AX=1203h (Set DOS Data Segment). How do We keep track of all these INT 21h AH=12h subfunctions? It's time to take a closer look.

Tracing a DOS INT 2Fh Call

To examine the code for INT 21h AH=52h, we're going to disassemble the DOS INT 2Fh handler just as we did for INT 21h Read. But we first need DEBUG to execute through a single INT 2Fh call so we can find the DOS INT 2Fh handler. We could do the same thing again, but as explained such as INT 21h AX=1200h (DOS Internal Services) are undocumented (check out appendix B). Is there a way to automate using DEBUG to trace, perhaps trace through interrupts and locate the entire interrupt chain without DEBUG's help?

How Does DEBUG Trace Through an INT?

First you have to understand a little of how the DEBUG trace command works. There's a section of *Undocumented DOS* (and a separate chapter by Tim Paterson on debugging) with extensive source code examples on the disk (see UNDOC CHAP7.ASM). This is an excellent place to turn for a general discussion of how DEBUG works.

Debugging tools and debuggers such as DEBUG and SYMDEB uses the single step feature built into the 80x86 microprocessors. When the processor's trace flag (TF) is enabled, the processor issues an INT 1 after every instruction it executes. A debugger can install an INT 1 single step handler to allow the effect of having a breakpoint on every instruction.

Unfortunately, a single step handler contains code to clear and leave TF enabled on entry to the single step handler. Several instructions in useless loop. For this reason, the processor temporarily disables the trace flag after it services an interrupt and reenables tracing when the interrupt handler returns. In fact, the processor disables single step for *all* interrupts.

Intel's documentation suggests several ways to trace through an INT. To trace through an INT, a debugger must set a breakpoint at the first instruction of the interrupt handler and then reenable single stepping in the breakpoint's interrupt handler (see Crawford and Gelsinger, *Programming the 80386*). This is what DEBUG does. Unfortunately, the MSDOS family of debuggers (included with the first edition of *Undocumented DOS*) happened not to trace through INT instructions.

INTCHAIN

We can incorporate this knowledge into a program that single steps through an interrupt handler. INTCHAIN does exactly this. It sets an INT 1 single step handler, turns on the trace flag, issues the interrupt call specified on the program's command line, and turns off the trace flag. Because INTCHAIN causes control to transfer to an INT, the processor calls the single step handler. The single step handler saves the current interrupt handler chain. The handler saves away CS:IP whenever CS changes. It looks for the first interrupt handler that is chaining to the previous handler. When the chain is broken, INTCHAIN has turned off the trace flag. INTCHAIN prints out the interrupt chain saved by the single step handler.

Let's apply INTCHAIN to the SMARTDRV code in Figure 6-5 that SMARTDRV does back-to-chaining of the DOS Disk Reset function (INT 21h AH=0Dh). This is plainly visible in an INTCHAIN trace of a call to this function, shown in Figure 6-10a.

Figure 6-10a: INTCHAIN Display for INT 21h AH=0Dh (Disk Reset)

```
C:\UNDOC2\CHAP6>intchain 21/0d00
1387 instructions
Skipped over 4 INT

0B94:3286   MSCDEX
07EA:15EA   SMARTDRV
C861:0829
0255:0025   J
C7C0:058E   DB.$SYS$
0516:109F   DOS
FDC8:40F8   HMA
0070:06F5   IO
FDC8:8655   HMA
0070:C7D9   IO
FFFF:0043   HMA
CC2C:0625   DB.$SYS$
07EA:1631   SMARTDRV
```

Notice that after being processed by MSDOS.SYS, IO.SYS and DBLSYS$, the call winds up back in SMARTDRV.

For a closer comparison with the DEBUG trace in Figure 6-3, Figure 6-10b presents sample INTCHAIN output for tracing an INT 21h AH=62h call.

Figure 6-10b: INTCHAIN Display for INT 21h AH=62h

```
C:\UNDOC2\CHAP6>intchain 21/6200
77 instructions
```

```
DF93:32B6   MSCDEX
07F9-15FA   SMARTDRV
CB01:0800
0255:0023   D:
CC2E:058E   D8.SSYSS
D116:109E   DOS
FDC8:40F8   HMA
```

Sure enough, this matches the interrupt chain we so laboriously traced back in Figure 6-3. INTCHAIN uses MAP.C from Listing 6-2 to try to match up CS:IP addresses with the names of resident TSRs and drivers. The addresses displayed by INTCHAIN can be passed to SYMDEB or DEBUG for disassembly—this is the whole point of the program.

INTCHAIN can also trace through an XMS function or an arbitrary segment:offset pointer. Actually, the program has little to do with interrupt chains as such. Rather than generate an actual INT instruction and then have to mess with setting a breakpoint, the program just turns an INT XXh into a far call and PUSHF to the handler for INT XXh. Thus, INTCHAIN won't trace through any INT generated inside the handler, such as the INT 2Ah call made by the INT 21h dispatcher in Figure 6-1—this is generally what you want anyway.

Listing 6-5: INTCHAIN.C

```
/*
INTCHAIN.C
Andrew Schulman, May 1993
Copyright (C) 1993 Andrew Schulman  All rights reserved

bcc intchain.c map.c

Uses single-step to trace through interrupt chains
usage:   intchain intno/ax/bx/cx/ds
example: intchain 21/6200
*/

#include <stdlib.h>
#include <stdio.h>
#include <string.h>
#include <dos.h>

typedef unsigned char BYTE;
typedef unsigned short WORD;
typedef unsigned long DWORD;

#ifdef __cplusplus
typedef void interrupt (far *INTRFUNC)(...);
#else
typedef void interrupt far *INTRFUNC)(void);
#endif

typedef void (far *FARFUNC)(void);

#ifndef MK_FP
#define MK_FP(s,o)  ((((DWORD) s) << 16) + (o))
#endif

#define MK_LIN(fp   ((((DWORD) FP_SEG(fp)) << 4) + FP_OFF(fp))

#pragma pack(1)

typedef struct {
#ifdef __TURBOC__
    WORD bp,di,si,ds,es,dx,cx,bx,ax;
#else
```

```
    WORD es,ds,di,si,bp,sp,bx,dx,cx,ax;     /* same as PUSHA */
#endif
    WORD ip,cs,flags,
    } REG_PARAMS;

#define INT_INSTR       0xCD
#define TRACE_FLAG      0x100

extern char *find_owner(DWORD lin_addr);    // in map.c

void fail(const char *s) { puts(s); exit(1); }

#define MAX_ADDR        512

static WORD volatile instr = 0, int_instr = 0;
static WORD prev_seg = 0, my_seg = 0;
static void far * *addr;
static int num_addr = 0;

void interrupt far single_step(REG_PARAMS r)    // INT 1 handler
{
    WORD seg;
    BYTE far *fp;

    if ((seg = r.cs) == my_seg)             // ignore my own code
        return;

    fp = (BYTE far *) MK_FP(r.cs, r.ip);
    if (fp[0] == INT_INSTR)                 // count INTs
        int_instr++;
    instr++;

    if  seg  = prev_seg)                    // if segment changed,
    {                                       // assume we've chained
        if (num_addr < MAX_ADDR)
            addr[num_addr++] = (void far *) fp;
        prev_seg = seg;
    }
}

#define GET_FLAGS(reg)  _asm { pushf } ,  asm { pop reg }
#define SET_FLAGS(reg)  _asm { push reg } , _asm { popf }

void set_flag(unsigned mask)
{
    GET_FLAGS(ax);
    _asm or ax, word ptr mask
    SET_FLAGS(ax);
}

void clear_flag(unsigned mask)
{
    GET_FLAGS(ax);
    _asm mov bx, word ptr mask
    _asm not bx
    _asm and ax, bx
    SET_FLAGS(ax);
}

FARFUNC get_xms(void)
{
    _asm mov ax, 4300h
    _asm int 2fh
    _asm cmp al, 80h
    _asm je present
```

```
absent:
    fail("XMS not present");
present:
    _asm mov ax, 4310h
    _asm int 2fh
    _asm mov ax, bx
    _asm mov dx, es
    // retval in DX AX
}

main(int argc, char *argv[])
{
    static int intrfunc = 0;    /* make sure not in a register */
    INTRFUNC old_sstep;
    FARFUNC func = (FARFUNC) 0;
    FARFUNC xms_func = (FARFUNC) 0;
    void far **p;
    char *s;
    WORD intno, _ax, _bx, _cx, _dx;
    int a20off = 0;
    int i;

    puts("INTCHAIN 1.0 -- Walks interrupt chains");
    puts("From \"Undocumented DOS\", 2nd edition (Addison-Wesley, 1993)");
    puts("Copyright (C) 1993 Andrew Schulman. All rights reserved.\n");

    if (argc < 2)
        fail("Usage: intchain [-a20off] <intno,xms seg ofs>/ax/bx cx/dx");

    if (strcmp(strupr(argv[1]), "-A20OFF") == 0)
    {
        xms_func = get_xms();
        a20off++;
        argv++;
    }

    // figure out what code they want to generate:
    // an XMS call
    if (strcmp strupr argv[1]), "XMS", 3) == 0)
    {
        func = get_xms();
        sscanf(argv[1], "XMS:%04X:%04X:%04X:%04X",
            &_ax, &_bx, &_cx, &_dx);
        printf("Tracing XMS at %Fp\n", func);
    }
    // ... or a far (segment:offset) CALL
    else if (strchr(argv[1], ':'))
    {
        WORD seg, ofs;
        sscanf(argv[1], "%04X:%04X:%04X:%04X:%04X:%04X",
            &seg, &ofs, &_bx, &_cx, &_dx);
        func = (FARFUNC) MK_FP(seg, ofs);
        printf("Tracing function at %Fp\n", func);
    }
    //     or an INT XXh
    else
    {
        sscanf(argv[1], "%2x:%04x:%04x:%04x:%04x",
            &intno, &_ax, &_bx, &_cx, &_dx);

        /* single step doesn't go through INT, so turn the INT into
           a PUSHF and far CALL */
        if (! (func = (FARFUNC) _dos_getvect(intno)))
            fail("INT unused");
        intrfunc++;     // so do PUSHF when call func
```

```
        printf("Tracing INT %02X AX=%04X\n", intno, _ax);
    }
    if (! (addr = (void far **) calloc(MAX_ADDR, sizeof(void far *))))
        fail("Insufficient memory");
    fp = (void far *) main;
    my_seg = FP_SEG(fp);
    old_sstep = _dos_getvect(1);
    _dos_setvect(1, (INTRFUNC) single_step);
    if (a20off)
    {
        _asm mov ah, 6
        (*xms_func)();  // local disable A20 line
    }
    set_flag(TRACE_FLAG);
    /* call the code */
    _asm mov ax, _ax
     asm mov bx, _bx
     asm mov cx, _cx
    _asm mov dx, _dx
    if (intrfunc)
        _asm pushf
    (*func)();

    clear_flag(TRACE_FLAG);
    _dos_setvect(1, old_sstep);
    printf("%u instructions\n", instr);
    if (int_instr)
        printf("Skipped over %u INT\n", int_instr);
    printf("\n");
    for (i=0; i<num_addr; i++)
    {
        s = find_owner(MK_LIN(addr[i]));
        printf("%Fp\t%s\n", addr[i], s? s : "");
    }
    if (num_addr == MAX_ADDR)
        fail("Overflow: very long INT chain");
    return 0;
}
```

Examining The INT 2Fh Chain

You can now use INTCHAIN to trace through a call to INT 2Fh AX=1200h, without using DEBUG. Figure 6-11 shows sample results. Note that the configuration is somewhat different from the one used to produce the INTCHAIN output for INT 21h AH=62h in Figure 6-10.

Figure 6-11: INTCHAIN Display for INT 2Fh AX=1200h

```
C:\UNDOC2\CHAP6>intchain 2f/1200
174 instructions
Skipped over 1 INT

1248:0007   NLSFUNC
109A:0980   PRINT
0F16:0943   SHARE
0B18:0285   DOSKEY
0B94:3080   MSCDEX
07FA:1368   SMARTDRV
0726:019F   COMMAND
0725:0135   COMMAND
C801:0696
0725:018D   COMMAND
FFFF:0FD8   HMA
```

```
C801:061E
0255-0020   J.
CC2C:25E0   DBLSSYS$
0255.0028   J:
CC2C-0116   DBLSSYS$
D116:1DC6   DOS
FDCB:44BD   MMA
```

Toward the goal of disassembling DOS, the essential piece of information here is the very last line, as this gives the address FDCB:44BD of MSDOS.SYS's INT 2Fh handler. We will come back to this in a few moments.

The most noticeable feature of Figure 6-11 is the very long interrupt chain. NLSFUNC, PRINT, SHARE, DOSKEY, MSCDEX, SMARTDRV, COMMAND.COM, and DoubleSpace all take a crack at processing the call. Processing, even when as you'll see an absolute error, a INT 2Fh AX=1200h call requires the transient DSR and device driver swapped out of INT 2Fh's space. The call to set the interrupt then INT 21 exhaustive, causing this are particularly bad when any interrupt handlers wrapper code is the wrappers from Chapter 2 are invoked. As noted earlier, Ralf Brown has suggested an alternate INT 2Fh protocol in an attempt to shorten these long chains of handlers that get run for INT 2Fh calls that appear.

Naturally, you can pass any of the addresses displayed by INTCHAIN to a debugger such as DEBUG or SYMDEB. For example, take the 0894:308D handler for INT 2Fh which INTCHAIN shows belong to the Microsoft CD-ROM Extensions.

```
-u 894:308d
0894:308D 9C            PUSHF
0894:308E 80FC11        CMP     AH,11
0894:3091 7503          JNZ     3096
0894:3093 EB6B          JMP     3100
0894:3095 90            NOP
0894:3096 80FC15        CMP     AH,15
0894:3099 7503          JNZ     309E
0894:309B EB09          JMP     30A6
0894:309D 90            NOP
0894:309E 80FC05        CMP     AH,05
-
```

You can see MSCDEX just checking for calls to INT 2Fh AH=11h. This makes perfect sense, as INT 2Fh AH=11h is the network redirector protocol, and MSCDEX is a network redirector (see Chapter 8). MSCDEX can also make calls to INT 2Fh AH=15h as well, again makes sense since this is the aforementioned MSCDEX API (see Ray Duncan's *MS-DOS Extensions*). What about INT 2Fh AH=05h? As explained in the upcoming Tip, this is an undocumented interface that allows resident programs (new to DOS 4.0) to report critical errors to others and to strings. External DOS programs such as COMMAND.COM issue INT 2Fh AH=05h calls network redirectors such as MSCDEX handle error codes. For example, the value with this range to display such as "CDR001 Not ready reading drive D" is stored in CDR's recording of Hands's *Wizard*.

How about INT 2Fh under Windows? Figure 6-12 shows INTCHAIN output for the same configuration as Figure 6-11, except that INTCHAIN is running in a DOS box under Windows Enhanced mode.

Figure 6-12: INTCHAIN Display for INT 2Fh AX=1200h Under Windows Enhanced Mode

```
Tracing INT 2F AX=1200
175 instructions

1404:02A7   win
12E4-0068   WINICE
1248:0007   NLSFUNC
109A:0980   PRINT
```

```
0F1e 0943   SHARE
DB18 0285   DOSKEY
0894 3080   MSCDEX
07FA 1368   SMARTDRV
0726 019F   COMMAND
0725 0135   COMMAND
C801 0696
1580 0045   win386
0725 018F   COMMAND
FFFF 0FD8   HMA
C801 061E
0255 0020   J:
CC2C 25E0   DB.SSYS$
0255 0028   J:
CC2C 0116   DB.SSYS$
0116 10C6   DOS
FDC8 4480   HMA
```

Notice that WINCOM and WINDBG (the Soft-ICE Windows debugger) added themselves to the chain. Like INT 21h, we can put notice that WIN386 has inserted itself into the middle of the chain. This occurs just after the Ralf Brown's Interrupt List service interrupts have DOS boots Windows Enhanced mode. Windows device drivers and code that never show up in INT13.TXT or RBIL.TXT are also hooked into the chain. Many of these hooks are NT and CE code that hop into the Windows Virtual Machine Manager (VMM.386) to support protected mode. Even simple passthrough to a real mode DOS program like INT13.TXT hooks in Windows Enhanced mode hooks INT 2Fh using the protected mode interface described in the DDK. A more sophisticated version of INT13.TXT would need to be written to deal with Windows Enhanced mode. The same goes for INT13.TXT. Listing 6-13, which does at least recognize the VMPI instruction that Windows uses as a V86 breakpoint.

The MSDOS.SYS and IO.SYS INT 2Fh Handlers

You're ready for the information you've been waiting for. Figures 6-11 and 6-12 list the INT 2Fh handlers in the low memory area for INT 2Fh when DOS=HIGH. In this configuration the MS-DOS.SYS INT 2Fh handler is located at FDC8:4480. This code is shown with comments in Figure 6-13.

Figure 6-13 MSDOS.SYS INT 2Fh Handler from MS-DOS 6.0

```
-u fdc8 44bd
FDC8 4480 FB            STI
FDC8 4481 80FC11        CMP   AH,11        ; 2F/11 network redirector call?
FDC8 4484 750A          JNZ   4490        ; no

    unsupported functions come here.  Some external programs like SHARE,
   NLSFUNC or a redirector is supposed to handle these.  If we got here,
   the external program must not be loaded, so it's an error     except
   if the caller is doing a 2F/1100 installation check, in which case DOS
   must return AX unchanged to indicate the software isn't installed

FDC8 4486 0AC0          OR    AL,AL       ; 2F/1100 installation check?
FDC8 4488 7403          JZ    448D        ; yes, unsupported funct, AX unchanged
FDC8 448A E81CFF        CALL  43A9        ; no -- set carry flag for error
FDC8 448D CA0200        RETF  0002        ; sort of IRET without changing flags

FDC8 4490 80FC10        CMP   AH,10       ; 2F/10 SHARE call?
FDC8 4493 74F1          JZ    4486        ; yes: error
FDC8 4495 80FC14        CMP   AH,14       ; 2F/14 NLSFUNC call?
FDC8 4498 74EC          JZ    4486        ; yes: error
FDC8 449A 80FC12        CMP   AH,12       ; 2F/12 DOS internal function?
FDC8 449D 7503          JNZ   44A2        ; no  keep checking
FDC8 449F E91102        JMP   46B3        ; yes  goto fig 6-15a
FDC8 44A2 80FC16        CMP   AH,16       ; 2F/16 Windows call or broadcast?
```

```
FDC8 44E2 7400        JZ    44F1        ; yes  DOS communicate with Windows
FDC8 44E4 80FC46      CMP   AH,46       ; 2F/46  misc  DOS Windows func?
FDC8 44E7 7503        JNZ   44EC        ; no  jump to IO SYS INT 2Fh hand er
FDC8 44E9 E988D1      JMP   46A4        ; yes  goto 2F/46 handler
FDC8:44EC EA05007000  JMP   0070 0005   ; pass to IO SYS  fig  6-14
```

With the exception of Figure 6-13, we've seen a hardware jump to 0070:0005. Here MSDOS.SYS intercepts this jump and adds a patch to the INT 2F call. It passes it on to IO.SYS and then intercepts INT 2Fh handler. Code Compaq Increases these two DOS INT 2Fh handlers register contents to DOS by the time we've stepped as we install our first glance at the IO.SYS INT 2Fh handler, which is shown in Figure 6-14. Note that when DOS HIGH, IO.SYS is assigned at A20 is already on, so control path into IO.SYS's INT 2Fh handler is through the code in MSDOS.SYS which actually took care of enabling A20. It is low memory switch located at 0:6 (DOS 6 in Figures 6-13 and 6-14).

Figure 6-14: IO.SYS INT 2Fh Handler from MS-DOS 6.0

```
-u 70:5
0070:0005 EA93087000      JMP     0070 0893

-u 70:893
0070:0893 2EFF2EE60e      JMP     FAR CS [06E6]

-dd 70.6e6 6e6
0070.06E6  FFFF 1302

-u FFFF 1302
FFFF:1302 80FC13          CMP     AH,13     ; 2F/13 (set INT 13h handler) call?
FFFF:1305 7413            JZ      131A      ; yes: do it
FFFF 1307 80FC08          CMP     AH,08     , 2F/08 DRIVER SYS call?
FFFF 130A 7438            JZ      1347      , yes  do it
FFFF 130C 80FC16          CMP     AH,16     , 2F/16 Windows call?
FFFF 130F 7479            JZ      138A      ; yes: IO.SYS also handles these!
FFFF:1311 80FC4A          CMP     AH,4A     , 2F/4A  M sc  undoc func  call?
FFFF:1314 7503            JNZ     1319      , no  return unchanged
FFFF:1316 E9A700          JMP     13C0      , yes  do  t
FFFF:1319 CF              IRET
```

There [illegible] would speed up DOS boot and disk I/O. Set INT 2Fh handler INT 2Fh. All [illegible] MSDOS.SYS and IO.SYS [illegible] Windows Node [illegible] have to [illegible] DOS [illegible] INT 2Fh [illegible] DOS [illegible] INT 2Fh [illegible]

Examining the MSDOS.SYS Handler for INT 2Fh AH=12h

In Figure 6-3 [illegible] the handler for these functions. We [illegible] this address [illegible] Figure 6-15a shows the results.

Figure 6-15a: MSDOS.SYS Handler for INT 2Fh AH=12h

```
-u 1dc8 46f0
FDC8 46F0 2EFF36783F      PUSH    CS:[3F78]   ; word at FDC8:3F78 = 44CAh
FDC8.46F5 2EFF367A3F      PUSH    CS:[3F7A]   ; word at FDC8:3F7A = 3F7Ch
FDC8 46FA 50              PUSH    AX          ; push function/subfunction
FDC8 46FB 55              PUSH    BP
FDC8:46FC 8BEC            MOV     BP,SP
FDC8 46FE 8B460E          MOv     AX,[BP+0E]  , put possible stack arg  nto AX
FDC8:4701 5D              POP     BP
FDC8:4702 E84509          CAL     5D4A        , call subroutine (fig  6-15b)
FDC8:4705 E9BFFD          JMP     44C7
```

Here [illegible] What's this supposed to do?

Figure 6-15b: More MSDOS.SYS Code for INT 2Fh AH=12h

```
-u fdc8 504a
FDC8 504A 55            PUSH    BP                      ;
FDC8 504B 8BEC          MOV     BP,SP
FDC8 504D 53            PUSH    BX
FDC8 504E 8B5E06        MOV     BX,[BP+06]      , address of subfunc table
FDC8 5051 2E8A1F        MOV     BL,CS:[BX]      , number of valid subfuncts
FDC8 5054 385E04        CMP     [BP+04],BL      , caller's subfunction number
FDC8 5057 7317          JNB     5070            , if too high, error
FDC8 5059 8A5E04        MOV     BL,[BP+04]      , get subfunction
FDC8 505C 32FF          XOR     BH,BH
FDC8 505E D1E3          SHL     BX,1            , turn into word offset
FDC8 5060 43            INC     BX              , skip past # subfunctions
FDC8 5061 035E06        ADD     BX,[BP+06]      , add in address of table
FDC8 5064 2E8B1F        MOV     BX,CS:[BX]      , pull out func ptr
FDC8 5067 895E06        MOV     [BP+06],BX      , push on stack, RET to it
FDC8 506A 5B            POP     BX
FDC8 506B 5D            POP     BP
FDC8 506C 83C404        ADD     SP,+04
FDC8 506F CB            RETF                    , call subfunc via RETF
FDC8 5070 5B            POP     BX              , invalid subfunc come here
FDC8 5071 5D            POP     BP
FDC8 5072 C20600        RET     0006
```

Despite the confusing look of Figure 6-15b, it is not specifically related to INT 2Fh AH=12h subfunctions. In fact, all subfunctions use the same subroutine. For example, the handler for INT 2Fh AH=13h calls the same subroutine. The top of Figure 6-15a shows that calling this subroutine pushes a word of information on the stack, including AX, which holds the function and subfunction of the caller's request. For example, 1200h in AX is the address of a table of function pointers. The code also checks to see if the number of valid subfunctions, the first byte of the table, is an array of near function pointers. The appropriate handler for each subfunction.

The subroutine in Figure 6-15b takes the caller's subfunction number, for example, the 00h in 1200h, and compares it to the first byte of the table to see if it is within that range. If it is, the code shifts the subfunction number into a word and adds it to the address of the table. The value is incremented by 4 to skip past the table's first byte. The subroutine then pulls the function pointer out of the table, pushes the word on the stack, and returns to it.

Locating the INT 2Fh AH=12h Dispatch Table

There's a sequence of debug commands to follow, but for our purposes, the key piece of information is the location of the table, as this holds pointers to every INT 2Fh AH=12h subfunction. At the top of Figure 6-15a, the code that handles calling the table's configuration. The table is at FDC8:3F7D. The first byte of the table is the number of subfunctions. This is followed immediately by an array of 30h words holding function pointers to the various INT 2Fh AH=12h subfunctions.

```
-db fdc8 3f7c 3f7e
FDC8 3F7D                               30                      0

-dw fdc8 3f7d
FDC8 3F7D  470E 6E2E 4C8E 4708 9066 54EB 9342 98EA
FDC8 3F8D  6F2F 9A9F D38F 6B6A 6853 48CE 5030 98E3
FDC8 3F9D  5030 4139 5011 9011 9927 9A76 A6A3 AB12
FDC8 3FAD  4282 AABB AECD 4978 4A92 496C 4FD7 A9FC
-
```

Let's see this already for INT 2Fh AH=12h's dispatch table. Earlier, it was noted that the subroutine at 4282h that DOS was fond of calling contains the code for INT 2Fh AX=1218h, Get Call Back Registers. Using SYMDEB to dump the table entry #18h confirms that this is correct.

```
-dw fdc8 3f7d+(18*2)
FDC8 3FAD  4282 ....
```

The FTAB program (see Listing 6-4) can produce a user display of this same table. In fact, FTAB has an option to display tables such as this that keep the number of subfunctions as the first byte. The two commands shown (see Listing 6-16) are thus equivalent. So that you have a handy 21h 12h reference to refer to, the entire table is shown, along with comments indicating the purpose of each subfunction.

Figure 6-16: INT 2Fh AH=12h Dispatch Table Displayed by FTAB

```
C:\UNDOC2\CHAP6>ftab fdc8:3f7e 30 int2f12

C:\UNDOC2\CHAP6>ftab fdc8 3f7d ? int2f12
FDC8:470E    int2f12_00      ; install check
FDC8:6E2E    int2f12_01      ; close current file
FDC8 4CBE    int2f12_02      ; get interrupt addr
FDC8 4708    int2f12_03      ; get dos data seg
FDC8 9066    int2f12_04      ; normalize path separator
FDC8 54EB    int2f12_05      ; output char
FDC8:9342    int2f12_06      ; invoke crit err
FDC8,98EA    int2f12_07      ; make disk buff most recently used
FDC8,6F2F    int2f12_08      ; decrement sft ref count
FDC8 9A9F    int2f12_09      ; flush and free disk buff
FDC8 B38F    int2f12_0A      ; perform crit err interrupt
FDC8 686A    int2f12_0B      ; signal share violation
FDC8:6853    int2f12_0C      ; set fcb file's owner
FDC8:48CE    int2f12_0D      ; get date and time
FDC8 5030    int2f12_0E      ; mark all disk buffer unreferenced
FDC8:98E3    int2f12_0F      ; make buffer most recently used
FDC8:5030    int2f12_10      ; find unreferenced disk buffer
FDC8 4FF9    int2f12_11      ; normalize asciiz filename
FDC8 5011    int2f12_12      ; strlen
FDC8 9011    int2f12_13      ; toupper
FDC8 9927    int2f12_14      ; _fstrcmp
FDC8 9A76    int2f12_15      ; flush buffer
FDC8 A6A3    int2f12_16      ; get address of SFT entry
FDC8:AB12    int2f12_17      ; set working drive
FDC8,4282    int2f12_18      ; get caller's registers
FDC8,AA8B    int2f12_19      ; set drive
FDC8 AECD    int2f12_1A      ; get file's drive
FDC8 4978    int2f12_1B      ; set year, length of february
FDC8 4A12    int2f12_1C      ; checksum memory
FDC8 496C    int2f12_1D      ; sum memory
FDC8 4FD7    int2f12_1E      ; compare filenames
FDC8 A9FC    int2f12_1F      ; build CDS
FDC8 A66C    int2f12_20      ; get JFT entry
FDC8 AEA8    int2f12_21      ; truename
FDC8 4434    int2f12_22      ; set extended err info
FDC8 8147    int2f12_23      ; check if char dev
FDC8 5030    int2f12_24      ; delay
FDC8 501F    int2f12_25      ; strlen
FDC8 5004    int2f12_26      ; open file
FDC8 A72A    int2f12_27      ; close file
FDC8 50DA    int2f12_28      ; move file pointer (lseek)
FDC8 A839    int2f12_29      ; read file
FDC8 5094    int2f12_2A      ; set fastopen entry point
FDC8 5117    int2f12_2B      ; ioctl
FDC8:5106    int2f12_2C      ; get dev chain
FDC8 5134    int2f12_2D      ; get extended err code
FDC8 5139    int2f12_2E      ; get/set error table addresses
FDC8 4400    int2f12_2F      ; nop
```

The whole reason I'm looking at INT 2Fh AH=12h was that we expected that many of the near functions that DOS makes internally would show up here. Indeed, you can now see clearly that the CALL 4282 that has come to be popped upon these explorations is actually INT 2Fh AX=1218h. Such a

Earl promises earlier CALL 4000 is actually INT 21h AX=5220h Get DOS Entry. DOS interrupt makes extensive use of the functions in Figure 6-16 but, as already noted, it does so using a near CALL. Another reason an INT DOS provides the INT form mostly for use by redirectors (see Chapter 8). The next code fragment disassembles INT 21h AH=12h functions definitely makes it much easier to understand what's going on in these INT 21h function calls, so which one we're interested.

Recall in Figures 6-11 and 6-12, the process of locating this table started by having the INT 21h AH=52h program call INT 21h AX=1200h. This function tells the DOS internal services install check, returning with AL=FFh to indicate that the services are present. The table indicates that DOS 4.01 uses a caller for this function. Let's disassemble at this address to check that the table makes sense.

```
-u 1dc8 470e
1DC8:470E B0FF        MOV     AL,FF
1DC8:4710 CB          RETF
```

However, INT 2F AX=1203h which is supposed to return with the DOS data segment in DS?

```
-u 1dc8 4708
1DC8:4708 2E8E1EE730      MOV     DS,CS:[30E7]
1DC8:470D CB              RETF
```

Let's look at one more to see if we can't find a more interesting function. According to the appendix, INT 2F AX=12xx uses a DOS's working. Here, the caller must push a zero-based drive number on the stack before calling the function. According to Figure 6-16, this function is located at 1DC8:AB12. Figure 6-17 shows a commented DEBUG disassembly of this code.

Figure 6-17: INT 2Fh AX=1217h (Set Working Drive) in MS-DOS 6.0

```
-u 1dc8:ab12
;;; BX points at DOS DS.
;;;   DS = SysVars is at DOS:0026, so DOS:0047 is SysVars+21h
1DC8:AB12 3A5A064700      CMP     AL,SS:[0047]    ; SysVars+21h = LASTDRIVE
1DC8:AB17 7202            JB      AB1B            ; is drive < LASTDRIVE?
1DC8:AB19 F9              STC                     ; no: set carry flag, fail
1DC8:AB1A CB              RETF
1DC8:AB1B 53              PUSH    BX              ; yes
1DC8:AB1C 50              PUSH    AX
1DC8:AB1D 368E1E3C00      MOV     DS,SS:[003C]    ; SysVars+16h = CDS ptr
1DC8:AB22 B358            MOV     BL,58           ; 58h   size of CDS entry
1DC8:AB24 F6E3            MUL     BL
1DC8:AB26 03F0            ADD     SI,AX           ; DS:SI = ptr to drive's CDS
;;; Here, SDA at DOS:0320, so DOS:05A2 is SDA+282h
1DC8:AB28 368936A205      MOV     SS:[05A2],SI    ; move drive's CDS ptr into
1DC8:AB2D 368C1EA405      MOV     SS:[05A4],DS    ;    DOS SDA+282h
1DC8:AB32 58              POP     AX
1DC8:AB33 5B              POP     BX
1DC8:AB34 F8              CLC
1DC8:AB35 CB              RETF
```

Even if you haven't read all the books on the stack, you may wonder how the code starts out with a reference to AL. Look up stack at Figure 6-15, note that the generic INT 2Fh AH=12h handler pushes AX on the stack. BP+0 is created after the caller's CS:IP and flags, and since AX is a word, it's the first parameter that doesn't expect a parameter on the stack, AX holds a word-sized value. It's not unusual that DOS makes an INT 2Fh AX=12xxh call; this is just a short cut. AX=1203h is saying that DOS wants to call the code for INT 2Fh AX=1200h, and that any parameter which the INT 2Fh version would appear on the stack (see the appendix) actually appears in AX.

Everything else in this function involves fairly straightforward manipulation of DOS internal structures. The function checks the drive number against the internal value of LASTDRIVE in SysVars. If

the drive number is valid, the function uses it as an index into the CDS array—a pointer (2 words) which is also contained in SysVars—the function then moves a pointer to the CDS entry into a DOS global variable. Changing this variable is basically what it means to set DOS's working drive.

It is useful to see how DOS internals uses the LASTDRIVE variable in SysVars, the CDS, and other undocumented DOS features. Discussions of undocumented DOS are often as to be left out of this book, disconnected from any consideration of DOS internals. But the CDS, SFT, List of Lists, and other structures are not provided for our entertainment, like the hidden "gang screens" that software hobbyists and cryptanalysts search for upon finding. In fact, the CDS and so many are not so much undocumented DOS features as *internal* DOS features that happen to be externally accessible through an undocumented interface. That undocumented DOS is often discussed without the surrounding context of DOS internals leads to the real purpose of these structures.

For example, even though this chapter has often referred to the location of variables such as CURR_PSP as SDA+10h or ERR_AH_LAST as SDA+1h, without DOS more values mean nothing, as the Swappable Data Area. The SDA is merely an externally visible interface that Microsoft added rather late in the DOS data segment scene. Origins of the SDA, in Chapter 8. Likewise, the INT 2Fh AH=12h functions are just undocumented external interfaces provided on top of some internal DOS functions. Or, to be more exact, most of network redirectors. The internal vs. all form of these functions is the true one.

What have we accomplished so far basically by locating the INT 21h AH=12h dispatch table, we now acquire some 80+ different external DOS functions. Or, rather, uncovering of the INT 21h dispatch table gives us entries for 101 different locations in DOS. Rather than keep picking at disassembly of individual functions here and there, we can now turn around and obtain a full blown disassembly of this entire code segment.

Really Disassembling DOS

Interesting, we've found that a DOS system data code segment would, in this particular configuration happens to be, in DOS. Of course, there are other parts of DOS, but this segment seems like a good place to start. How to go about disassembly of the entire code segment, but once found, keep track of where the individual functions are located. For example, in a monster disassembly of segment 0DC8h, we would like to know where the Set PSP function is located, where Close is located, and so on.

You can use DEBUG or SYMDEB to produce a disassembly of the DOS code segment, then use the LIAS program to produce a list containing the locations of key functions within the segment. To merge the LIAS output with the disassembly and while we're about it, clean up and improve the disassembly, I wrote a small program named NICEDBG.exe in MASM. Its C-like pattern matching language is ideal for text processing tasks like this.

To disassemble the entire DOS code segment, you first need to know where to tell DEBUG to start and stop. To do so, you can make a preliminary stab at finding the proper unassembly range by taking the 1st and last entries of the INT 21h dispatch table (segment 0C8h) and the INT 21h AH=12h dispatch table (segment 0DC8h), sorting them, and sorting them by address.

```
C:\UNDOC2\CHAP6>type tmp.bat
@echo off
ftab fdc8:3e9e 6d INT21 > int212f.tmp
ftab fdc8:3f7d 30 INT2F_12 >> int212f.tmp
sort < int212f.tmp > int212f.log

C:\UNDOC2\CHAP6>tmp

C:\UNDOC2\CHAP6>type int212f.log
FDC8 4052   INT21 33
```

```
FDC8 4DA9    INT21_50
FDC8 4DB5    INT21_51
FDC8 4DB5    INT21_62
FDC8 4DC1    INT21_64
FDC8 42B2    INT2F_12_1B
FDC8 4400    INT21_1B
;    etc
FDC8 BDE9    INT21_5A
FDC8 B1B3    INT21_6C
FDC8 B2D8    INT21_5C
FDC8.038F    INT2F_12_0A
```

[illegible] the first few lines of INT21.ODG it's clear that you want DEBUG or SYMDEB to [illegible] FDC8:4DA2 and [illegible] somewhere around after FDC8:B38F. BS00 is probably [illegible]. You'll probably need to adjust the [illegible] assembly range later on. Return to DEBUG [illegible]. Now create the assembly command into a DOS script file and feed it to the [illegible] with DOS's output redirected to a file:

```
C:\UNDOC2\CHAP6>type int2121.scr
u fdc8:4da2 b500
q

C:\UNDOC2\CHAP6>debug < int2121.scr > int2121.out
```

[illegible] SYMDEB rather than DEBUG produces a cleaner result. SYMDEB puts segment overrides on [illegible] rather than on the instruction as a separate line like DEBUG does, but you must use SYMDEB's [illegible] switch. SYMDEB's /NOI prompt, which you wouldn't see if you redirected output to a file:

```
C:\UNDOC2\CHAP6>symdeb /x < int2121.scr > int2121.out
```

[illegible] The INT21.ODG file is about 87K bytes, much smaller than the SYMDEB [illegible] because it omits the [illegible] for example. It's also much [illegible] DOS function starts. One of the things NUKEDBG can do is merge the INT2F.12 OR 1 [illegible] by DEBUG or SYMDEB with the INT2121.ODG file produced using [illegible]

Windows Patches MS-DOS

Actually, there's one interesting thing you can do with the raw unassembly output from DEBUG or SYMDEB. Run the DEBUG unassembly script once under MS DOS, then start Windows Enhanced mode and rerun the DEBUG script again from inside a DOS box. Redirect DEBUG's output to a different file. This sequence gives you an easy way to examine the patches that Windows applies to MS DOS. Just compare the two files, using diff or a similar utility. Any differences in the DOS code segment are the result of Windows patches:

```
C:\UNDOC2\CHAP6>debug < int2121.scr > int2121.out

C:\UNDOC2\CHAP6>win

;;; from inside DOS box:
C:\UNDOC2\CHAP6>debug < int2121.scr > int2121.win

C:\UNDOC2\CHAP6>diff int2121.out int2121.win > int2121.dif
```

The list of Windows patches in INT212F.DIF is incomplete, because it shows only one DOS code segment. Still, it does provide some idea of what is going on:

```
;; original MS-DOS code in INT 21h dispatch (see Figure 6-7 above)
< FDC8:41CE 50            PUSH  AX
< FDC8:41CF B482          MOV   AH,82
< FDC8:4101 CD2A          INT   2A
< FDC8:4103 58            POP   AX

;; patched by Windows, 15AD belongs to WIN386.EXE
> FDC8:41CE 9A0A00AD15    CALL  15AD:000A
> FDC8:4103 90            NOP

;; original DOS code in a frequently called internal Begin Crit 01 function
< FDC8:514B B80180        MOV   AX,8001
< FDC8:514E CD2A          INT   2A

;; patched by Windows
> FDC8:514B 9A4300AD15    CALL  15AD:0043

;; original DOS code in a frequently called internal End Crit 01 function
< FDC8:516B B80181        MOV   AX,8101
< FDC8:516E CD2A          INT   2A

;; patched by Windows
> FDC8:516B 9A7900AD15    CALL  15AD:0079

;  ..  etc.
```

The DOSMGR VxD built into WIN386.EXE applies these patches. When Windows exits, DOSMGR, of course, backs its changes out, restoring the original DOS code. As you can see, these patches have to do with DOS critical sections. DOSMGR wants DOS to call into the Windows VMM Begin Critical Section and End Critical Section functions. It's important to note that DOSMGR scans for the INT 2Ah instructions to patch, rather than using hardwired addresses. Thus, these patches should, at least theoretically, work with a different vendor's DOS.

The same before and after technique can be used to find DOS patches applied by other programs, such as MSCDEX. Programs that patch DOS can only be safely unloaded by a MARK/RELEASE type of program that knows enough about these patches to back them out.

Using NICEDBG

To run NICEDBG on the companion disk, feed it output from DEBUG or SYMDEB. Optionally, you can supply assembler code files or code segment/offset address pairs, such as EMM386 procedures. You can also supply NICEDBG with optional files of data segment/offset address pairs. For example:

```
debug < int212f.ser > int212f.out
ftab fdc8:3e9e 6d INT21 > int212f.log
ftab fdc8:3f7d 30 INT2F_12 >> int212f.log
nicedbg int212f.out int212f.log int212f.dat > int212f.lst
```

NICEDBG can take a few minutes to process a lengthy input from DEBUG or SYMDEB. The program makes several passes over the DEBUG listing, replacing calls and jumps to meaningless looking addresses such as 4F5A:3B2C with calls and jumps to more meaningful labels, provided by the user, such as INT21_12. It also creates some useful labels for any other addresses that are the target of calls or jumps. It can also get address information from a REL or MAP file. NICEDBG changes the label to reflect this information and generates a list of cross-references to each location.

For example, a snippet of code from DEBUG looks like this:

```
FDC8:5126 9C              PUSHF
FDC8:5127 36              SS:
```

```
FDC8 5128 803E0C0D00    CMP BYTE PTR [0D0C],00
FDC8 512D 740F          JZ  513E
FDC8 512F EB01          JMP 5132
FDC8 5131 CF            IRET
FDC8 5132 0E            PUSH    CS
FDC8 5133 E8FBFF        CALL    5131
FDC8 5136 50            PUSH    AX
FDC8 5137 B80180        MOV AX,8001
FDC8 513A CD2A          INT 2A
FDC8 513C 58            POP AX
FDC8 513D C3            RET
FDC8 513E EB01          JMP 5141
FDC8 5140 CF            IRET
FDC8 5141 0E            PUSH    CS
FDC8 5142 E8FBFF        CALL    5140
FDC8 5145 C3            RET
```

Lots is not very promising looking. But NUEDBG can transform this raw disassembly listing into something much more readable and useful:

```
; xref: FDC8:4304 FDC8:4380 FDC8:4D7A
                        func_5126:
FDC8 5126   9C              PUSHF
FDC8 5127   36803E0C0D00    CMP BYTE PTR SS:[0D0C],00
FDC8 512D   740F            JZ jmp_513E  -> loc_5141
FDC8 512F   EB01            JMP loc_5132

; xref:  FDC8 5133
                        ret_5131:
FDC8 5131   CF              IRET

; xref:  FDC8 512F
                        loc_5132:
FDC8 5132   0E              PUSH CS
FDC8 5133   E8FBFF          CALL ret_5131
FDC8 5136   50              PUSH AX
FDC8 5137   B80180          MOV AX,8001
FDC8 513A   CD2A            INT 2A
FDC8 513C   58              POP AX
FDC8 513D   C3              RET

; xref:  FDC8 512D
                        jmp_513E:
FDC8:513E   EB01            JMP loc_5141

; xref:  FDC8 5142
                        ret_5140:
FDC8 5140   CF              IRET

; xref:  jmp_513E
                        loc_5141:
FDC8:5141   0E              PUSH CS
FDC8 5142   E8FBFF          CALL ret_5140
FDC8 5145   C3              RET
```

Here are some of the changes that NUEDBG made at various offsets in the code:

- 5126: Generated a cross reference listing (xref) and a func_5126 label because this location is CALLed from three other places elsewhere in the code. To generate such labels and xrefs, NUEDBG of course must make multiple passes over the DEBUG listing.
- 5127: Combined the SS: override together with the rest of the instruction at 5128.
- 5128: Replaced "JZ 513E" with "JZ jmp_513E -> loc_5141". 513E is the target of the JZ at 5128. Because 513E itself does an unconditional JMP, NUEDBG gives it a jmp_513E label.

Furthermore, NICEDBG chases down JMPs to JMPs and shows the final destination. Here, for example, the DOS code contains many JMPs to JMPs. Knowing the ultimate destination of the JMP can make the code a little easier to understand and also suggests a possible area for DOS optimization.

- 5131: Skipped a blank line because 5131 is the target of another instruction and because it starts a new block and because 5131 can be reached from the preceding line at 512E. NICEDBG also takes an additional JMP. NICEDBG generated the label based on the ALT to this location from 5133. Finally, because the code at this location does an immediate IRET, NICEDBG gave it a ret 5131 label.
- 5132: Again, NICEDBG skipped a blank line because 5132 is the target of another instruction and because 5132 can't be reached from the preceding line, which does an IRET. NICEDBG generated a low 5132 label.

NICEDBG uses low to specify targets of jumps or calls, high to specify targets of CALLs, loop to specify targets of LOOPs, ret to specify code that is reached from somewhere else by a RET or IRET, and jump to specify code that does an unconditional JMP. If the user supplies a symbol table file of name/address pairs, it is generated with LIB. NICEDBG will use this as a source of labels.

NICEDBG.AWK, listing 6.6, is the source code for this postprocessor for output from DEBUG or SYMDEB.

What Is AWK?

Since the reader is likely to be unfamiliar with AWK, a brief explanation of Listing 6.6 is probably called for. AWK reads in each line of text in one or more files and splits the line into fields. You can change the delimiters that AWK uses to decide where fields start and end, but it defaults to using white space, which is exactly what we need here. The fields are available to the program as $1, $2, and so on, up to $NF (NF is a built-in AWK variable that holds the number of fields). $0 is the original line. For example, the line "FDC8:440D INT21 1D" is $0. FDC8:440D is $1, and INT21 is $2 (and $NF).

Note too that AWK handles regular expressions as also found in utilities such as grep. For example, the regular expression "[DES]S" matches "CS", "DS", "ES", or "SS", and "\[.*\]" matches anything within square brackets. AWK also has associative arrays (just built-in hash tables, really) that can be indexed with strings (for example, array["string"]) as well as numbers. The presence of an item in an associative array can be tested with the in operator, for example, if ("string" in array).

The standard reference is *The AWK Programming Language* by Alfred Aho, Brian Kernighan, and Peter Weinberger, from the first letters of whose last names the language got its name. The high-level pattern-matching and array features of AWK make it possible to implement NICEDBG in about 200 lines of code.

NICEDBG.EXE on the accompanying disk was produced with the excellent AWK compiler from Thompson Automation. You can run the program without having AWK or understanding anything about it, but to modify the program, you would need Thompson AWK or another AWK interpreter or compiler. The popular MKS Toolkit comes with AWK, and many BBSs carry MAWK, a freely available fast AWK interpreter by Mike Brennan.

NICEDBG processes each line in the DEBUG file. For example, consider the following line from a DEBUG listing:

```
FDC8:5120 740F          JZ   5131
```

AWK breaks this line into fields delimited by spaces. The *n*th field is referred to as $*n*

```
$1    FDC8:512D          Address of the instruction
$2    740F               Instruction opcode bytes
$3    JZ                 Instruction operator
$4    513E               Instruction operand
```

Of course, not every instruction looks quite like this. For example:

```
   $1     $2             $3  $4   $5     $6
FDC8:5126 9C             PUSHF
FDC8:5127 36             SS:
FDC8 5128 803E0C0000     CMP BYTE PTR [0C0C],00
```

in any case, NICEDBG's AWK can rely on $1 as the address of the instruction and on $3 as either the instruction operator or, when reassembling DEBUG rather than SYMDEB, something like a segment override.

Before processing the DEBUG file, NICEDBG reads in the optional symbol table and data files. NICEDBG uses INT21H.LOG or any similarly formatted file to build a table of names called *ftab* corresponding to service-call offset locations: the program runs through each line in INT21H.OUT or any disassembly listing produced by DEBUG or SYMDEB to see if the line's segment:offset address is in the table.

NICEDBG makes three passes over the DEBUG file.

Pass 1 NICEDBG looks for any calls, jumps or loops in the code and adds the target of the call, jump or loop to *ftab*, which I will later use to generate labels. Simplifying considerably, the AWK code looks like this:

```
if ($3 ~ /CALL/) ftab[$4] = "func_" $4;
if ($3 ~ /LOOP/) ftab[$4] = "loop_" $4;
if ($3 ~ /J.*/)  ftab[$4] = "loc_" $4;
```

On pass 1, NICEDBG also constructs the *jmptab* for resolving JMPs to JMPs:

```
if ($3    /JMP/)   jmptab[$1]   $4;    # jmptab[SOURCE] = TARGET
```

Pass 2 The second time through the DEBUG file, NICEDBG builds its *xref* table and also improves on the *ftab* constructed on pass 1. A label such as *jmp_XXXX* or *ret_XXXX* indicating that location XXXX does an unconditional JMP or IRET is generally more useful than a label such as *loc_XXXX*, indicating that XXXX is the *target* of a jump. Thus if pass 1 assigned a location a name, and that location has a JMP or a IRET, NICEDBG changes *ftab* to reflect this:

```
if ($3    /IRET/ && ($1 in ftab)) ftab[$1] =  ret_  $1,
if ($3    /JMP/) && ($1 in ftab))   ftab[$1] =  jmp_  $1,
```

As on pass 2, NICEDBG looks for code that may be "not reached" that is not accessible from anywhere in the listing. Of course, the code might be called from outside the disassembly range. If the previous instruction was an unconditional JMP or IRET and if there are no labels at the current address (i.e., *ftab*[$1] is empty), indicating that $1 is not the target of a jump, call, or loop, NICEDBG adds $1 to a *not_reached* array:

```
if ((did_jmpret == 1) && (! ($1 in ftab))) not_reached[$1]++;
did_jmpret = 0;
if ($3 ~ /IRET|JMP/) did_jmpret = 1;
```

Pass 3 In its final pass over the DEBUG listing, NICEDBG prints out the new, improved listing.

- If the current line was not reached (i.e., $1 is in *not_reached*), NICEDBG indicates this with a comment: this might be a sign either of data or of "dead code."

- If the current line has one or more labels (e.g., SI in Table 6-4), NICEDBG prints them out, one per line. Either the user will have supplied these labels in a symbol table file, or NICEDBG will have generated them automatically in passes 1 and 2.
- If any other line of code jumped, called, or looped to this line of code, NICEDBG displays the cross reference.
- If the code itself calls, jumps, or loops to some other line of code, NICEDBG replaces the numeric target with a name from Table 6-4 (Table 6-4).
- If the target of the call, jump, or loop is a line of code that itself does an unconditional JMP, NICEDBG chases down any JMPs to JMPs; see the resolve_jmp_jmp() function in Listing 6-6.
- If the user supplied a file of data address name pairs, NICEDBG uses it to replace expressions such as [0330], with names provided by the user, such as [CURRENT_PSP]. Recall that an earlier inspection of Get PSP and Set PSP (Figures 6-3 and 6-4) showed that these functions do nothing more than get and set a word at offset 0330h in the DOS DS. Thus, a DOS reference of [0330] in an unassembly of DOS can *probably* be replaced with a name such as CURR_PSP. Likewise, examination of INT 21h AH=33h (Figure 6-5) showed that DOS 0069h is STARTUP_DRV and that 033Eh is BRK_FLAG. You can feed this sort of information to NICEDBG in a file of data address name pairs such as INT212F.DAT:

```
0069        STARTUP_DRV
0330        CURR_PSP
0337        BRK_FLAG
30E7        DOS_DS
1030        IN_WIN3E
033E        MACHINE_ID
0321        IN_DOS
0584        USER_SP
0586        USER_SS
0320        CRIT_ERR
1211        DOS_HIGH
```

  But note that NICEDBG's replacements of, for example, [0330] with CURRENT_PSP are very simple-minded. The program merely does a blind global search and replace. Thus you should be very conservative about what you put in a NICEDBG .DAT file.
- If DEBUG or, after that, SYMDEB was used to produce NICEDBG's input, NICEDBG saves away any segment override on the current line (DS:, CS:, ES:, etc.) and uses the AWK substitute() function to attach it to the proper place on the next line.

Listing 6-6: NICEDBG.AWK

```
# NICEDBG.AWK -- Produces nicer output from DEBUG input and symbol table
# usage: nicedbg symtab dbgfile  [dbgfile ...]
# example: nicedbg int212f.log int212f.out  int212f.lst

# get offset from seg:ofs
function get_ofs(addr)      { split(addr, so, ":"); return so[2]; }

function mk_fp(ofs)         { return seg ":" ofs; }  # make seg:ofs farptr

function get_ftab_name(addr) {  # get name from table
    if (addr !~ /:/)
        addr = mk_fp(addr);     # table indexed by seg:ofs
    if (! (addr in ftab))
        return addr;            # not there -- return unchanged
    split(ftab[addr], label, ",");
    return label[1];            # just return first name if >1
    }
```

```
function resolve_jmp_jmp(src) { # JMP to JMP to . .
    if (! (src in jmptab))
        return,
    if (done[src])
        return done[src],
    # if get here, haven't seen this one yet
    target = target2 = jmptab[src],
    while (target in jmptab)    {
        target2 = jmptab[target];
        if (target2 == target)      # endless loop
            break,
        if (target2 == src)         # cycle
            break,
        if (target2 in done) {      # we've seen this part already
            target2 = done[target2],
            break,
            }
        target = target2,
        }
    done[src] = target2;
    return target2;
    }

function hex(x)     { return 0 + ("0x" x), }    # relies on Thompson AWK

BEGIN {
    print  NICEDBG    Makes nicer output from DEBUG input and symbol table",
    print  From \"Undocumented DOS\", 2nd edition (Addison-Wesley, 1993)";
    print  Copyright (c) 1995 Andrew Schulman  All rights reserved \n ,
    if (ARGC < 2)  {
        print  usage  nicedbg dbgfile [symtab] [datfile]  [stdfile" ,
        print  example  nicedbg int212f out int212f log  int212f lst" ,
        did_anything = 0;
        exit;
        }
    else did_anything = 1,

    # commonly-used regular expressions
    SQ_BRACK    / [ ^\]]/,                  # anything within square brackets
    SEG_OFS = /\:/;                         # has a : in it
    SEG_OVERRIDE    /(CDES)S\ /,            # CS  or DS  or ES. or SS:
    CALL_OR_JUMP = /CALL|LOOP|J */,         # CALL, LOOP, JMP, J*

    # read in optional symbol-table file
    # lines in symtab file look like:  xxxx:yyyy    name
    if (ARGC < 2) {
        while (getline < ARGV[2])       # for each line in symbol table
            ftab[$1] = ftab[$1] $2 ",", # put name into table for seg:ofs
        close(ARGV[2]),
        }

    # read in optional data file
    # lines in data file look like:     xxxx   name
    # example:                          0521   IN_DOS
    if (ARGC < 3)   {
        while (getline < ARGV[3])
            data[$1] = $2,
        close(ARGV[3]),
        }

    ARGC = 2;                           # finished with sym, dat file
    dbgfile = ARGV[1];                  # switch over to DEBUG file

    # debug file looks like.    xxxx:yyyy   XXXXXX   op operands
    # example:                  FDC8:4052   3C06     CMP AL,06    ; comments
```

```
while (getline < dbgfile)   {       # make pass 1 through debug file
    if ($1 ~ SEG_OFS) {
        split($1, so, ":");
        if (! seg)  {
            seg = so[1];            # get segment for later use
            start = hex(so[2]);
            }
        else
            stop = so[2],           # take last one
        }
    if ($3 ~ CALL_OR_JUMP)  {
        if ($4 ~ /  ]\[ *\]|FAR/)  # don't do [xxxx] or xxxx.yyyy etc
            continue,
        # should also ignore e g  CALL 9I
        if ($3 ~ /JMP/)
            jmptab[get_off($1)] = $4,   # jmptab for resolving JMP JMP
        if (! (mk_fp($4) in ftab))      # put call/jmp target into table
            ftab[mk_fp($4)] = (($3 ~ /CALL/) ? "func_" :
                               ($3 ~ /LOOP/) ? "loop_" : "loc_") $4,
        }
    }
close(dbgfile),
stop = hex(stop);

# pass 2: build cross-ref table, improve some label names, etc.
while (getline < dbgfile)   {
    if ((did_jmpret == 1) && (! ($1 in ftab)))
        not_reached[$1]++, # prev line did JMP/RET, but no label, so
    did_jmpret = 0,        #     not reached", may be data or dead code

    if ($3 ~ /[^*RET|JMP/)   {
        did_jmpret = 1,
        if ($1 in ftab)     # if target is a ret/jmp, change label name
            ftab[$1] = (($3 ~ /JMP/) ?  jmp_  :  ret_ ) get_off($1),
        # oops, this will also replace labels supplied in sym file!
        }
    # below "not" "else if  ~  JMP handled both places
    # build xref table and outside-range table
    if (($3 ~ CALL_OR_JUMP) && ($4 !~ SQ_BRACK) && ($5 !~ SQ_BRACK)) {
        if ($4 ~ /FAR/)
            outside[$5]++,
        else if ($4 ~ SEG_OFS)
            outside[$4]++,
        else {
            off = hex($4),
            if ((off  start) || (off  stop))
                outside[off]++;
            }
        if ($4 !~ /\:[FAR/)      # don't do [xxxx] or xxxx yyyy
            xref[mk_fp($4)] = xref[mk_fp($4)] get_ftab_name($1) " ",
        }
    }
close(dbgfile),
}

{                                   # pass 3: for each line in dbg file
while (! ($1   SEG_OFS)) {          # ignore any lines without xxxx.yyyy
    print, getline;
    if (! $0) exit,
    }

jmpline =   ,

# indicate if this is possible unreached (dead) code; show
# cross-reference (xref) table; show all labels for this address
```

```
    if ($1 in not_reached)  {                   # possible dead code
        print "
        print ";;; not reached!";
        }
    else if ($1 in ftab) {                      # if segment:offset in table
        print
        if (xref[$1])
            print "; xref: " xref[$1]          # show xref
        nf = split(ftab[$1], label, ",");
        for (i=1; i<=nf;i++)
            if (label[i])                       # show all labels for this addr
                printf("%24s%s:\n", " ", label[i]),
        ftab_found[$1] = 1;
        }

    # if a CALL, LOOP, or some kind of JMP, show eventual destination
    # of any JMP JMP, and possibly replace number address with string name
    if ($3 ~ /CALL|^J|LOOP/)  {
        if ($4 !~ /FAR/)    {
            if ($4 in jmptab)
                jmpline = "    " get_ftab_name(resolve_jmp_jmp($4));
            $4 = get_ftab_name($4);         # replace number with name
            }
        }

    # cheap replacement of [xxxx] with names from data file
    if (match($0, SQ_BRACK))                # match sets RSTART, RLENGTH
        if ((addr = substr($0, RSTART+1, RLENGTH-2)) in data)
            sub SQ_BRACK, data[addr], $0),  # sub() does substitution

    # get rid of DEBUG segment override ugliness
    if ($3 ~ SEG_OVERRIDE) {
        ovride_addr = $1;                   # save to use on next line
        byte = $2;
        override = $3;
        }
    else if (ovride_addr)   {
        $1 = ovride_addr; ovride_addr = "",
        $2 = byte $2;
        sub(/:/, override ":", $0),         # plug in override
        }

    # print out (possibly altered) line
    if (! ovride_addr)  {
        printf("%s\t%-15s\t", $1, $2);
        for (i = 3; i<= NF;i++)
            printf("%s ", $i),
        if (jmpline)
            printf("%s ", jmpline);
        printf("\n"),
        }
}

# print list of CALL, JMP, etc  references outside disasm range
END {
    if (did_anything) {
        printf("\n;; outside range %s %04X-%04X \n", seg, start, stop);
        for (x in outside)
            printf(";; " ((x ~ SEG_OFS) ? "%s" : "%04X") "\n", x);
        # should suppress following if within a not-reached block?
        printf("\n;; possible unresolved labels:\n"),
        for (x in ftab)
            if (! (x in ftab_found))
                printf(";; %s\n", ftab[x]);
        }
}
```

With output from DEBUG in INT212F.OUT, a symbol table produced by FLAB in INT212F.LOG, and the optional data file INT212F.DAT, you can produce a nice looking disassembly of the main MSDOS.SYS code segment, INT212F.LST, with

```
nicedbg int212f.out int212f.log int212f.dat > int212f.lst
```

We will examine this INT212F.LST file in more detail momentarily, but the following excerpt provides some idea of what NICEDBG produces:

```
                        INT2F_12_18:
FDCB:4282 2E8E1EE73D    MOV DS,CS:DOS_DS
FDCB:4287 C5368405      LDS SI,USER_SP
FDCB:428B C3            RET
; ...
                        INT21_34:
FDCB:4059 E826F5        CALL INT2F_12_18
FDCB:405C C7440221D3    MOV WORD PTR [SI+02],IN_DOS
FDCB:4061 8C5410        MOV [SI+10],SS
FDCB:4064 C3            RET
```

This is quite usable. You can see that INT 21h AH=34h, Get InDOS Flag Address, calls the code for INT 2Fh AX=1218h, Get Caller's Registers, and then moves DOS:DS:IN_DOS into the caller's ES:BX registers. This is just as you would expect.

You could make it even more readable by going into INT212F.LOG and taking the more partially useful names such as INT21_34 and INT2F_12_18 produced by FLAB and replacing them with more evocative names such as GET_INDOS_34 and GET_SYSVARPTR_1218. But this is left as an exercise for the reader, who may or may not know all the DOS functions by heart and not require such a crutch. The point is simple that you can manually change or add to INT212F.LOG as you learn new functions. For example, you can add the following two functions that you already know about from running INTCHAIN:

```
FDCB:40F8   INT21_DISPATCH
FDCB:448D   INT2F_DISPATCH
```

Please note that INT212F.LST is not included on the accompanying disk as redistributing a large piece of MS-DOS would obviously violate Microsoft's copyright. However, it should be easy for readers to produce their own copies, given the instructions in this chapter. To quickly summarize the steps involved in producing INT212F.LST:

1. INTCHAIN 21 6200 and use last line to locate DOS INT 21h handler
2. DEBUG or SYMDEB to disassemble INT 21h handler, locate dispatch table
3. Run FLAB on INT 21h dispatch table > tmpfile
4. INTCHAIN 2F 1200 and use last line to locate DOS INT 2Fh handler
5. DEBUG or SYMDEB to disassemble INT 2Fh handler, locate dispatch table
6. Run FLAB on INT 2Fh dispatch table >> tmpfile
7. SORT < tmpfile > symfile
8. Inspect top and bottom of symfile to create script for DEBUG or SYMDEB
9. DEBUG < script > outfile
10. Optionally create datafile
11. Optionally change and add to symfile
12. NICEDBG outfile symfile [datafile] > lstfile
13. Check "outside range" comment at end of lstfile. Possibly alter script and goto step 9

The last point needs an explanation. Because code and data are intermixed within DOS, DEBUG and SYMDEB are likely to encounter data that they will misinterpret as code. This should

work very well with the disassembly of valid code further on in memory. The result is that INT2F.2F:1ST may contain, for example, several CALLs to func_9024 but, instead of showing code at offset 9024h, there's instead some bogus looking instruction at offset 9023h. NIC.EDBG will list such "possible unresolved labels" at the end of the listing, so you can use this to split the DEBUG or SYMDEB command file into two or more parts. For example, let's say that there are valid looking calls to func_9024 but no func_9024 itself. If the original DEBUG script contained the following command

```
u fdc8:4052 b500
```

you'd split this in two, making DEBUG restart disassembly at offset 9024h:

```
u fdc8:4052 9024
u fdc8:9024 b500
```

At this point, of course, you may find a bit of postprocessing DEBUG output a little ridiculous. You may want to use a more powerful disassembler such as V Communications' Sourcer.

Remember that we've disassembled just one MSDOS.SYS code segment. You can apply the same techniques to other parts of MS-DOS, the outside range list produced by NIC.EDBG will help there, to DR-DOS or to NetWare's NET.EXE code.

Examining a Few DOS Functions

Let's look at a small portion of the MS-DOS 6.0 disassembly produced by DEBUG with a little help from TEMPLATE.TXT and NIC.EDBG. Figure 6-18 shows the code for a few simple DOS functions.

Figure 6-18: MS-DOS 6.0 Code for Functions 34h, 52h, 1Fh, 32h, and 0Dh

```
                        INT21_34:
FDC8:4059   E826F5          CALL INT2F_12_18
FDC8:405C   C7440221C3      MOV Word Ptr [SI+02],0321
FDC8:4061   8C5410          MOV [SI+10],SS
FDC8:4064   C3              RET

                        INT21_52:
FDC8:4065   E81AF5          CALL INT2F_12_18
FDC8:4068   C7440226C0      MOV Word Ptr [SI+02],0026
FDC8:406D   8C5410          MOV [SI+10],SS
FDC8:4070   C3              RET

                        INT21_1F:
FDC8:4071   B200            MOV DL,00

                        INT21_32:
FDC8:4073   16              PUSH SS
FDC8:4074   1F              POP DS
FDC8:4075   8AC2            MOV AL,DL
FDC8:4077   E8415D          CALL INT2F_12_19
FDC8:407A   7222            JB loc_409E
FDC8:407C   C43EA205        LES DI,[05A2]
FDC8:4080   26F6454480      TEST Byte Ptr ES:[DI+44],80
FDC8:4085   7517            JNZ loc_409E
FDC8:4087   E8B003          CALL func_513A
FDC8:408A   E83769          CALL func_96C4
FDC8:408D   E8CA03          CALL func_515A
FDC8:4090   720C            JB loc_409E
FDC8:4092   E8EDF4          CALL INT2F_12_18
FDC8:4095   896C02          MOV [SI+02],BP
FDC8:4098   8C440E          MOV [SI+0E],ES
FDC8:409B   32C0            XOR AL,AL
FDC8:409D   C3              RET
```

```
; xref  FDC8:4D7A FDC8:4D85 FDC8:4D90
                        Loc_4D9E:
FDC8:4D9E   B0FF            MOV AL,FF
FDC8:4DA0   C3              RET

                        INT21_0D:
FDC8:4DA1   B0FF            MOV AL,FF
FDC8:4DA3   16              PUSH SS
FDC8:4DA4   1F              POP DS
FDC8:4DA5   E89203          CALL func_513A
FDC8:4DA8   830E11D604      OR Word Ptr [D611],+04
FDC8:4DAD   E8846C          CALL func_9A34
FDC8:4DB0   83261D6FB       AND Word Ptr [D611],-05
FDC8:4DB5   C70685000000    MOV Word Ptr [0085],0000
FDC8:4DBB   BBFFFF          MOV BX,FFFF
FDC8:4DBE   891E2000        MOV [0020],BX
FDC8:4DC2   891E1E00        MOV [001E],BX
FDC8:4DC6   E89103          CALL func_515A
FDC8:4DC9   B8FFFF          MOV AX,FFFF
FDC8:4DCC   50              PUSH AX
FDC8:4DCD   B82011          MOV AX,1120
FDC8:4DD0   CD2F            INT 2F
FDC8:4DD2   58              POP AX
FDC8:4DD3   C3              RET
```

First of all notice that the two functions (INT 21h AH 34h and 52h) are nearly identical. Except for the values of the code displacements (Figure 6-18 shows how to compensate for this), the two functions are nearly identical. They both get the caller's stack structure and create different values into the caller's AX. Perhaps MOV [1DB6],AX could be optimized by using the caller's register structure and the words appropriately which would be helpful in preparing explicit expressions such as SI-02 and SI-10 with something like CALLER AX and CALLER IN (assuming version 7.0).

More disassembly will reveal that what appears to be in Figure 6-18 for INT 21h functions 1Fh and 32h. These DOS functions have not been well documented, which is why Microsoft has recommended that existing non-DOS INT 21h calls be used instead. Note that the code for function 1Fh simply sets DL = 0 and falls into the code for function 32h. This makes sense, since function 1Fh is Get Default Drive and function 32h is Get DPB for a Drive. If drive = 0, then get the default drive and return the DPB for the DS:BX.

When you ask for DPB for a drive, the Get DPB code calls several subroutines, as shown in Figure 6-19. Armed with the INT 21h Data Area, you can examine the code for each of these subroutines fairly easily. For example, INT 2Fh AH=11h and AH=32h are documented. So DOS must translate INT 21h AX=1219h into INT 2Fh AX=1219h. Sure enough, the INT 21h AX=12??h function dispatcher (Figure 6-17) shows that DOS sets DS = working data segment. Subroutine Set DS = DOS DS at DOS 05:A2E (SDA+282h). Note that this routine not only changes DS, it records the original DS in the DOS working data area. So when INT 2Fh AX=1219h has returned, Get DPB puts the original DS back. Now it can get the DOS DS back when the INT 2Fh function is complete. It then calls a subroutine that gets the DPB number from offset 45h in the CDS. Have examined the different subroutines that Get DPB calls, we can annotate the code with comments, as shown in Figure 6-19.

Figure 6-19: MS-DOS 6.0 Code for DPB Functions 1Fh and 32h

```
                        INT21_1F:
FDC8:4D71   B200            MOV DL,00               ; 0 = default drive
                                                    ; fall through!
                        INT21_32:
FDC8:4D73   16              PUSH SS
FDC8:4D74   1F              POP DS                  ; get DOS DS
FDC8:4D75   8AC2            MOV AL,DL
FDC8:4D77   E8415D          CALL INT2F_12_19        ; Set Drive, Coke 2f/1217
FDC8:4D7A   7222            JB loc_4D9E
FDC8:4D7C   C43EA205        LES DI,[05A2]           ; SDA+282h = curr CDS ptr
```

```
FDC8 4D80   26F6454480      TEST Byte Ptr ES:[DI+44],80 , CDS[43-44h] = flags
FDC8 4D85   7517            JNZ Loc_4D9E            , if net/redir drive, fail
FDC8 4D87   E88D03          CALL Func_513A          , enter crit #1 (2A/8001)
FDC8 4D8A   E83749          CALL Func_96C4          , ES:BP get DPB from CDS[45h]
FDC8 4D8D   E8CA03          CALL Func_515A          , exit crit #1 (2A/8101)
FDC8 4D90   720C            JB Loc_4D9E             ; fail?
FDC8 4D92   E8EDF4          CALL INT2F_12_18        , get caller's regs
FDC8 4D95   896CD2          MOV [SI+02],BP          , caller's BX
FDC8 4D98   8C44DE          MOV [SI+0E],ES          , caller's DS
FDC8 4D9B   32C0            XOR AL,AL               ; al = 0 for success
FDC8 4D9D   C3              RET
```

The external function we examined back in Figure 6-18 is INT 21h AH=0Dh Disk Reset. The function does its real work inside the call to func_9A34 (not shown), which loops over all buffers, calling the internal Flush Buffer routine. INT 2Fh AX=1215h. But note in Figure 6-18 that Disk Reset also calls INT 2Fh AX=1120h, which is the network redirector Flush All Disk Buffers function. This provides a good illustration of how the network redirector works as a series of *hooks* in DOS. At various key points, DOS issues an INT 2Fh. If the redirector installed redirector can pick up the call and do what it needs (see Chapter 8).

One of the things that probably won't occur to you from the DOS code shown in this chapter, but which becomes obvious when examining the INT 2Fh/12h INT table, is that hooks play an important role in DOS. In addition to the INT 2Fh/AH=12h internal interface, DOS also checks the SHARE hooks. These, however, are implemented in a totally different manner from the redirector (see SHAREHOOK.C at Listing 8-2 in Chapter 8). Of course, many DOS functions get passed down to installable device drivers. The DOS code also hooks into these by using the Strategy and Interrupt pointers in the device driver header (see Chapter 7).

Remember also that external programs probably hook many of these DOS calls. You saw earlier, for example, that SMARTDRV.SYS and DBLSPACE hook the Disk Reset call. Thus it is a little misleading to say that INT 21h AH=0Dh handler in MSDOS.SYS is so important. When examining the code for a DOS function, it is important to remember that DOS is not just the code in MSDOS.SYS and IO.SYS. Supplement your study of these internals of the code with a look at the DOS extensions you are likely to find on a typical machine. This not only means understanding the role of programs such as Windows, SMARTDRV, MSCDEX, DOSKEY, and ANSI.SYS, but also understanding where non-Microsoft products such as Stacker, NetWare, and 386MAX fit in. A good example of this is we saw in Chapter 4 is how even the originally simple Set DPB function suddenly take on new meaning and complexity when Novell NetWare is running.

Examining the DOS Lseek Function

As a more extensive, but still relatively self-contained example, let's examine the DOS Move File Pointer function, INT 21h AH=42h, frequently known as lseek after its C Unix equivalent. We had occasion to examine the DOS code for this function while working on Chapter 8 of this book. An early draft of the network redirector specification in Chapter 8 in discussing the redirector INT 2Fh AX=122F Seek From End function asserted that DOS never calls this function." Since this was based merely on empirical evidence—we never saw 2F 1122 called—I made sense to examine the DOS code to see if DOS did not contain a call to INT 2Fh AX=1322h.

To our surprise, the DOS code for seek *did* contain a call to this INT 2Fh function. It turns out that DOS does call the redirector's Seek From End function under a special set of circumstances having to do with network I/O and various SHARE modes. Frankly, we still don't quite understand this. In any case, the rest of the code for INT 21h AH=42h is fairly straightforward yet long enough to be a little more interesting than the feeble little examples we've seen so far. In addition, there is some interesting Windows-related code in DOS that we'll encounter along the way.

Before we examine the disassembly listing for INT 21h AH=42h, recall that the function has the following specification:

```
Move File Pointer
Input:
    AH = 42h
    AL = method (0 = from beginning, 1 = from current pos, 2 = from end)
    BX = file handle
    CX:DX = hi:lo offset from beginning, current, or end
    INT 21h
Output success
    Carry clear
    DX:AX = new hi:lo position
Output failure
    Carry set
    AX = error value (1 = invalid function, 6 = invalid handle)
```

Microsoft's DOS programmer's reference further notes that:

> A program should never attempt to move the file pointer to a position before the start of the file. Although this action does not generate an error during the move, it does generate an error on a subsequent read or write operation. A program can move the file pointer to beyond the end of the file. On a subsequent write operation, MS-DOS writes data to the given position in the file, filling the gap between the previous end of the file and the given position with undefined data. This is a common way to reserve file space without writing to the file.

This suggests that almost any CX:DX parameters to seek are valid. Indeed, as we'll see, the code does little more than move the CX:DX parameter into the file's SFT entry. The hard part is getting the SFT entry. To make sense of the code listing, you'll need to know a bit of trivia about the SFT. For further information, see the appendix under INT 21h AH=52h:

```
02h     WORD        open mode
05h     WORD        device info word
11h     DWORD       file size
15h     DWORD       current file position
2Fh     WORD        machine number (Windows VM ID)
```

Figure 6-20 shows the DOS code for INT 21h AH=42h, Move File Pointer. Many explanatory comments were added by hand to the code generated by NU.EXE/DBG.

Figure 6-20: MS-DOS 6.0 Code for INT 21h AH=42h (lseek)

```
; xref: FDC8:50D5 FDC8:9D52 FDC8:9DC1 FDC8:9E9C
                        INT21_42
FDC8:A845   E8E100          CALL func_A929 , TURNS BX HANDLE INTO
                                           ; ES:DI SFT (see fig. 6-21)
; xref: FDC8:A8B4
                        loc_A848
FDC8:A848   7302            JNB loc_A84C
FDC8:A84A   E89E            JMP jmp_A7EA  -> loc_43ED   ; couldn't fail!

; xref: loc_A848
                        loc_A84C                ; ES:DI=valid SFT entry
FDC8:A84C   3C02            CMP AL,02           ; which move method?
FDC8:A84E   760A            JBE loc_A85A
FDC8:A850   3E0606230301    MOV Byte Ptr SS:[0323],01 ; SDA+3=error locus
FDC8:A856   B001            MOV AL,01               ; 1=invalid function

    ; note many jmp jmp in DOS code:
    ;   A858 -> A7EA -> A708  > A7D4 -> A716 -> A6FB -> 45ED
    ; usually to use short jmp, but is it still worth it?
```

```
    ; but can it ever be changed??

, xref  jmp_A8AB
                        jmp_A858:
FDC8 A858   E890            JMP jmp_A7EA   > loc_43ED  , fail'

, xref  FDC8 A84E
                        loc_A85A:
FDC8 A85A   3C01            CMP AL,01
FDC8 A85C   720A            JB loc_A868                 , below = 0
FDC8 A85E   771B            JA loc_A879                 ; above = 2

                            , handling seek method #1: from current pos
FDC8 A860   26035515        ADD DX,ES [DI+15]           , SFT->file_pos
FDC8 A864   26134017        ADC CX,ES [DI+17]
                            , fall through to method #0

, xref  FDC8 A85C FDC8 A88A
                        loc_A868:               , #0, from beginning
FDC8 A868   8BC1            MOV AX,CX
FDC8 A86A   92              XCHG AX,DX                  ; DX:AX <- CX:DX

, xref  FDC8 A8A9
                        loc_A86B:
FDC8 A86B   26894515        MOV ES [DI+15],AX   , update SFT->file_pos
FDC8 A86F   26895517        MOV ES [DI+17],DX
FDC8 A873   B8FF99          CALL [NI]2F_52_1B   , get caller's regs
FDC8 A876   895406          MOV [SI+06],DX      , move into caller's DX
                            ;;; later on, loc_43FB does MOV [SI], AX
                            ;;; see table 6-2 for caller reg struct

; xref: jmp_A8EF
                        jmp_A879:
FDC8 A879   EBA7            JMP jmp_A822  -> loc_43E4   , success'

, xref  FDC8 A85E
                        loc_A87B:                   ; #2  from end
FDC8 A87B   26F6450680      TEST Byte Ptr ES:[DI+06],80 , dev info: NETWORK
FDC8 A880   750A            JNZ loc_A88C

, xref  FDC8 A891 FDC8 A8A2
                        loc_A882:
FDC8 A882   26035511        ADD DX,ES [DI+11]           , SFT->file_size
FDC8 A886   26134015        ADC CX,ES [DI+13]           , CX DX <- file_size
FDC8 A88A   EBDC            JMP loc_A868                , go to method #0

, xref  FDC8 A880
                        loc_A88C:               ; this is a network drive!

    ;;; this is seek method #2 (from end of file), and network bit is set
    ;;; in SFT  DOS may call a network redirector's 2F/1121 Seek From End
    ;;; handler, but only if some strange conditions are met  It can't
    ;;; be an FCB open, and certain SHARE bits must be set

FDC8 A88C   26F645038D      TEST Byte Ptr ES:[DI+03],80 , open mode: FCB'
FDC8 A891   75EF            JNZ loc_A882                ; an FCB open
                                        ;;; this is not an FCB open ;;;
FDC8 A893   26884502        MOV AX,ES [DI+02]           , open mode
FDC8 A897   25F000          AND AX,00F0
FDC8 A89A   3D4000          CMP AX,0040     , OPEN_SHARE_DENYNONE
FDC8 A89D   7405            JZ DO_2F_1121   , redir seek from end
FDC8 A89F   3D3000          CMP AX,0030     ; OPEN_SHARE_DENYREAD
FDC8.A8A2   75DE            JNZ loc_A882    , no  update caller's regs

; xref: FDC8 A89D
```

```
                        DO_2F_1121
FDC8:A8A4   B82111          MOV AX,1121  ; Call network redirector's
FDC8:A8A7   CD2F            INT 2F       ; Seek from End function
FDC8:A8A9   73CD            JNB loc_A86B , update caller's DX:AX from SFT

; xref: jmp_A8F9
                        jmp_A8AB
FDC8:A8AB   EBAB            JMP jmp_A858    > loc 43ED        , fail
```

As you can see, the code can fail if the caller passes an invalid file handle in BX or an invalid seek method in AL. But other than this the function essentially does little more than update the current position in the file's SFT entry. Even the network redirector doesn't bother to send a packet across the network for a seek call without calling a network redirector function. We can summarize the function's operation in this way:

```
sft = get_sft(handle)  // see below
if (seek from begin) then set sft->file_pos = new_pos
if (seek from end) then (signed) new_pos += file_size, goto seek from begin
if (seek from current) then new_pos += sft->file_pos, goto seek from begin
set caller's new_pos (DX:AX) = sft->file_pos
```

We haven't explored the very first part of the INT 21h AH 42h handler, however. Before it calls a subroutine to locate the proper SFT, it calls function 3829 to turn the caller's BX file handle into a pointer in ES:DI. This is shown in Figure 6-21. The code for the 3829 calls is not to be overlooked because it's also an important MS-DOS interaction with Windows. A number of Windows services, including INT 2Fh functions 1605h and 1606h, are also called by other parts of MS-DOS. Which is the code for functions 3Fh and 68h.

Figure 6-21. MS-DOS 6.0 Code To Verify SFT Virtual Machine ID

```
; xref:  INT21_3E INT21_68 FDC8:A7E5 INT21_42 FDC8:A8B1 FDC8:A907
                        func_A929
                                                ; func_A62A turns BX handle
FDC8:A929   E81EFC          CALL func_A62A , into ES:DI SFT (fig. 6-22)
FDC8:A92C   721C            JB ret_A94A     ; percolate error up
    ; we had handle, but it could be for another DOS box!
FDC8:A92E   50              PUSH AX
FDC8:A92F   36F606301001    TEST Byte Ptr SS:IN_WINSE,01
FDC8:A935   7404            JZ loc_A93B
FDC8:A937   33C0            XOR AX,AX
FDC8:A939   EB08            JMP loc_A943

; xref: FDC8:A935
                        loc_A93B:                       , Windows running
FDC8:A93B   36A15E03        MOV AX,SS:MACHINE_ID
FDC8:A93F   2638452F        CMP AX,ES:[DI+2F]           , SFT.share_machine

; xref: FDC8:A939
                        loc_A943:                       ; okay
FDC8:A943   58              POP AX
FDC8:A944   7501            JNZ loc_A947
FDC8:A946   C3              RET

; xref:  FDC8:A944
                        loc_A947:                       , failure
FDC8:A947   B006            MOV AL,06                   ; "invalid handle"
FDC8:A949   F9              STC

; xref:  FDC8:A92C
                        ret_A94A:
FDC8:A94A   C3              RET
```

This code deals with the fact that under Windows Enhanced mode, it is possible to have multiple processes in different DOS boxes that happen to have the same PSP ID, though note that SYSTEM.INI has a UniqueDOSPSP setting. Normally the current PSP and a file handle are sufficient to specify a particular file. Under Windows Enhanced mode, the current virtual machine (VM) ID is also needed to specify an open file.

In this routine, DOS 4+ checks whether Windows Enhanced mode is running (see Chapter 1 for how DOS typically gets the IN_WINDOWS flag). It gets the current VM ID (see Chapter 1 to see how the DOSMGR.VxD provides DOS's MACHINE_ID word with the current VM ID) and then compares the current VM ID against the machine ID held at offset 2Ch in the SFT. If the SFT's machine ID doesn't match the current VM, the routine fails with error code 6 as if the handle in BX were not valid. This is a good precaution, but it can lead to another process that happened to have the same PSP in another DOS box.

We'll take a look through how DOS turns a file handle in BX into an SFT entry in ES:DI. This is accomplished by the func_A62A routine in Figure 6-22, which turns first the BX handle (which is really an index into the current PSP's Job File Table) into a FAR pointer equivalent to INT 2Fh AX=1220h. Then it uses the FAR pointer to get the SFT index and then turns the SFT index into an SFT entry address via INT 2Fh AX=1216h. The disassembly starts out with DOS's INT 2Fh AX=1220h handler. The A62A appears in the middle of the listing.

Figure 6-22. MS-DOS 6.0 Code To Turn File Handle into SFT Pointer

```
; xref  FDC8:4F01 func_A62A loc_A671 loc_A6EA loc_A70D FDC8:A90F FDC8:A924
                        INT2F_12_20
FDC8:A600  2E8E06073D       MOV ES,CS:DOS_DS        ; get DOS_DS
FDC8:A605  268E063003       MOV ES,ES:CURR_PSP      ; use current PSP
FDC8:A609  263B1E3200       CMP BX,ES:[0032]        ; # files in JFT
FDC8:A60E  7204             JB loc_A614
FDC8:A610  B006             MOV AL,06               ; invalid handle

; xref:  FDC8:A615
                        loc_A612                    ; fail
FDC8:A612  F9               STC
FDC8:A613  C3               RET

; xref:  FDC8:A60E
                        loc_A614                    ; file handle < # files
FDC8:A614  26C43E3400       LES DI,ES:[0034]        ; JFT ptr in PSP
FDC8:A619  03FB             ADD DI,BX               ; add on BX handle

; xref:s FDC8:A61D
                        ret_A61B:
FDC8:A61B  C3               RET                     ; return ptr -> SFT ndx

;;; code to turn handle in BX into SFT entry in ES:DI ;;;
; xref  FDC8:4EDC INT21_4400_01 INT21_4402_03 FDC8:6100 INT21_440A \
; FDC8:757B func_A929 FDC8:B27B
                        func_A61C
FDC8:A61C  E8E0FF           CALL INT2F_12_20    ; turn BX handle->ES:DI JFT
FDC8:A61F  72FA             JB ret_A61B
FDC8:A621  26803DFF         CMP Byte Ptr ES:[DI],FF ; unused?
FDC8:A625  7504             JNZ loc_A62B
FDC8:A627  B006             MOV AL,06               ; invalid handle
FDC8:A629  EBE7             JMP loc_A612            ; fail

; xref  FDC8:A629
                        loc_A62B:
FDC8:A62B  53               PUSH BX
FDC8:A62C  268A1D           MOV BL,ES:[DI]          ; JFT entry -> SFT index
FDC8:A62F  32FF             XOR BH,BH
```

```
FDC8:A63F   E80200          CALL INT2F_12_16        ; SFT index -> SFT ES DI
FDC8 A642   5B              POP BX
FDC8.A643   C3              RET

, xref: FDC8 6DF1 FDC8 A516 FDC8 A63F FDC8:A686
                        INT2F 12 16                 , SFT ndx -> ES:DI SFT
FDC8:A644   2E8E06D73D      MOV ES,CS DOS_DS        , get DOS DS
FDC8:A649   26C43E2400      LES DI,ES [002A]        , SysVars+4  > first SFT

; xref: FDC8:A65E
                        loc A64E                    , walk SFT chain
FDC8 A64E   263B5D04        CMP BX,ES [DI+04]       , SFT # fixes
FDC8 A652   720E            JB loc_A662             , in this table
FDC8:A654   262B5D04        SUB BX,ES [DI+04]       , subtract #files this SFT
FDC8 A658   26C43D          LES DI,ES [DI]          , follow  nked list
FDC8 A65B   83FFFF          CMP DI, DI              , end of SFTs?
FDC8.A65E   75EE            JNZ loc_A64E            ; loop to next SFT
FDC8 A660   F9              STC                     ; invalid SFT index
FDC8 A661   C3              RET                     ; fail!

; xref: FDC8 A652
                        loc_A662:                   ; in this SFT
FDC8.A662   50              PUSH AX
FDC8:A663   B83B00          MOV AX,003B             ; SFT each size entry
FDC8:A666   F6E3            MUL BL
FDC8 A668   03F8            ADD DI,AX               ; offset of this entry
FDC8 A66A   58              POP AX
FDC8 A66B   83C706          ADD DI,+06              ; skip past SFT header
FDC8 A66E   C3              RET
```

The basic sequence here is: BX handle → JFT entry → 2F 1220 → SFT ndx → SFT entry 2F 1216.

Recall that the file handle in BX is really an index into the current PSP's JFT. Thus the code for INT 2Fh AX=1220h gets the current PSP from the variable CURR_PSP and checks PSP:0032, which holds the maximum number of file handles available in this PSP. If the handle in BX is within the handle maximum, it uses the JFT size to check this code gets a FAR pointer to the JFT from PSP:0034, indexes BX into the JFT pointer yielding a far pointer in ES:DI to the file's JFT entry.

Each JFT entry is a single byte that holds an index into the SFT. 0FFh is returned as an unused entry. The code in Figure 6-22 ensures that the caller hasn't passed a file handle whose corresponding JFT entry is unused.

If DOS has located the SFT index that passes it to a function equivalent to INT 2Fh AX=1216h, which returns a pointer to the corresponding SFT entry. From the last paragraph above, we can see how this code works. DOS gets a pointer to the first SFT from SysVars+4 and walks the SFT chain comparing the SFT index against the number of files in each SFT until it finds the right one. DOS then multiplies the resulting SFT index by 3Bh, the size of an SFT entry in this version of DOS, and adds it onto the start of this SFT, to form an SFT entry.

That's it. We've now examined the DOS code for both directions. We've seen how the specification for INT 21h AH=3Fh is actually implemented in working code: how DOS gets from a file handle in BX to an SFT entry, how it can use this SFT to get and set the current file position and size, and how it can use the Windows VMM ID. But remember that even a DOS service is possible to intercept. For example, important third-party extensions such as NetWare hook the seek function. One reason for this is that the DOS kernel neglects to deal with whatever changes these might make to the behavior of seek.

We have now presented a small, random selection of extremely simple DOS functions viewed in isolation from key third-party DOS extensions. To properly discuss this simple DIR.EXE disassembly of 30 kbytes of DOS code would require an entire book. To fully appreciate any single function

examining its interactions with resident software such as SmartDrv, Windows, and NetWare could easily be the subject of several books. For further in-depth discussions of this code, see Chappell's *DOS Internals* and Mike Podanoffsky's *Dissecting DOS: A Guide Level Look at the DOS Operating System*. This forthcoming book is described in more detail later in this chapter.

Other Parts of DOS

As noted earlier, NUEDIBG places an "outside range" list at the end of a disassembly listing. This list includes locations that are called or jumped to in the listing, but which don't themselves appear in the listing. This list provides additional addresses for unassembly by DEBUG or SYMDEB.

For example, the disassembly of the MSDOS.SYS code segment includes the function INT 2F DOS_VTCH. As you know from the earlier investigation in Figure 6-13, the INT 2Fh handler in MSDOS.SYS jumps to the handler in IO.SYS. Here is how this shows up in the IN1212F.LST file produced by NUEDIBG:

```
; xref:  FDCB 446A FDC8 662F FDC8 6687 FDC8 66E0
                        jmp_446F
FDC8:446F    EA05007000      JMP 0070 0005

;

;; outside range FDC8 4045-8800
;; 0070 0005
;
```

You can use this one address, 0070:0005, as the starting point for a disassembly of the IO.SYS code:

```
C:\UNDOC2\CHAP6>symdeb                                                  <
-u 0070 0005 0005
0070 0005 EA95087000      JMP     0070 0895
-u 0070 0895 0895
0070 0895 2EFF2EE606      JMP     FAR CS [06E6]
 dd 0070 06e6 06e6
0070 06E0  FFFF 1302
 u FFFF 1302
FFFF:1302 80FC13          CMP     AH,13
FFFF:1305 7413            JZ      131A
FFFF:1307 80FC0B          CMP     AH,0B
FFFF:130A 7438            JZ      1347
FFFF:130C 80FC16          CMP     AH,16
FFFF:130F 7479            JZ      138A
FFFF:1311 80FC4A          CMP     AH,4A                                 ;'J'
FFFF:1314 7503            JNZ     1319
FFFF:1316 E9A700          JMP     13C0
FFFF:1319 CF              IRET
-q

C:\UNDOC2\CHAP6>type to.scr
u FFFF:1302 1319
q

C:\UNDOC2\CHAP6>symdeb /s < to.scr > to.out

C:\UNDOC2\CHAP6>nicedbg to.out > to.lst

C:\UNDOC2\CHAP6>type to.lst

;
;; outside range FFFF:1302-1319
;; 131A
;; 1347
;; 138A
;; 13C0
```

Now, of course, we expand the unassembly range for SYMDEB based on the addresses in the outside range list. Also we can start to create a file with symbolic names.

```
C:\UNDOC2\CHAP6>type io.scr
u ffff:1302 13c0
■

C:\UNDOC2\CHAP6>type io.sym
FFFF:1302    IO_INT2F
FFFF:131A    IO_INT2F_13
FFFF:1347    IO_INT2F_08
FFFF:138A    IO_INT2F_16
FFFF:13C0    IO_INT2F_4A

C:\UNDOC2\CHAP6>symdeb /x < io.scr > io.out

C:\UNDOC2\CHAP6>nicedbg io.out io.sym > io.lst

C:\UNDOC2\CHAP6>type io.lst
;
;; outside range FFFF:1302-13C0
;; 0070 0898
;; 174E
```

We continue in this way until no more unsolved references remain. As noted earlier, sometimes DEBUG and SYMDEB get thrown off track because of data residing in the middle of a code segment. Based on the NICEDBG messages, you may need to split a single U command in a DEBUG script into two or more separate U commands.

Of course, the techniques shown here for disassembly of portions of MS-DOS SYS and IO.SYS also work for any other resident software. In Figure 6-11, for example, we saw SMARTDRV, MSCDEX, DOSKEY, SHARE, PRINT, COMMAND.COM, and several others hooked onto the INT 2F interrupt chain. You can examine any of the addresses displayed by INT 2F,13 or DEBUG or SYMDEB for disassembly and processing by nicedbg. Again, I'll start with NICEDBG.

However, this time I want to disassemble separate programs such as SMARTDRV, MSCDEX, COMMAND, and PRINT, not just reference them in memory. Because these programs don't contain the segment movers, contrary to what the DOS kernel PRINT in particular is probably the most bizarre assembled piece of DOS as far as I'm now, so it's INSP writers at their craft. You can use a disassembler such as Sourcer to examine these programs.

Given the brevity of reverse engineering DOS, an almost infinite amount of information on DOS programming is available. To answer some question about DOS, look at the code running on your machine. Sometimes when you get stuck with a problem, the approach is that at some point a code fragment may not work as intended. Applications, patch DOS, DOS changes brought in much information from one version to the next. Describing software based on its source code, whether supplied or disassembled, can be the only way to find out what the software really does or how it can be dangerous to make assumptions that may change. There are no certainties here. Your best bet is to examine the source code but recognize how it may change, either because of future versions or because of unforeseen interactions with other software.

Am I Going to Jail for This?

Many programmers seem to lose sleep about the legality of what we've been doing in this chapter. Programmers frequently think that disassembling Microsoft's code is illegal and even that it's somehow a theft. However, moral or ethical issues aside, is it an offense punishable by a stiff prison sentence? We had better look into this now.

The following discussion of the legalities of disassembly was not written by an attorney and should not in any way be viewed as legal advice. However, I have benefited enormously from discussions with Gene K. Landy, a partner at the law firm of Shapiro, Israel & Weiner, P.C., in Boston. Any errors and misconceptions of course remain mine.

Landy is the author of a superb book/disk package, *The Software Developer's and Marketer's Legal Companion*, published by Addison-Wesley (1993), which includes several extremely useful discussions of reverse engineering. Chapter 1 discusses reverse engineering in the context of copyright, including the important Sega v. Accolade case. Chapter 2 discusses software trade secrets and confidentiality agreements. Chapter 11 covers shrink-wrap licenses and warranties and the standard shrink-wrap license limitation on reverse engineering, noting the important case of *Vault v. Quaid*. This is a fine book that every software developer will want to have in these troubled, legally complex times.

Will boilerplate agreements be void that you ran into up behind bars not for having seen the CIA in action at the beginning of the INT 21h dispatch code? Quite simply, because the standard license agreement that comes with all Microsoft products states, as plain as day:

3. OTHER RESTRICTIONS. You may not reverse engineer, decompile, or disassemble the software.

The very top of the license agreement states that "This is a legal agreement between you (either an individual or an entity) and Microsoft Corporation. By opening the sealed software package, you are agreeing to be bound by the terms of this Agreement."

Well, that settles it, doesn't it? By opening the Microsoft software you have entered into a binding agreement not to disassemble it. Even if disassembly were otherwise a legitimate activity, right?

Not. Numerous boilerplate provisions, whether shrink-wrap licenses are binding because of the way in which they arise. Below are cases that have decided issues of shrink-wrap licenses, have spread further down the road about Landy's view. As Landy explains in his chapter on shrink-wrap licenses:

> In contrast to the accepted shrink-wrap license is a system of acceptance or rejection. If you accept the contract, you can open the envelope; if you reject it, you return the package for a refund. In this "accept/reject" concept of law, does the law really allow the licensor to force the user to this choice?
>
> The law of contract has come from its eighteenth-century roots to the present, as the courts wrestle with the question of a "meeting of the minds." In a classic contract, the law is to be enforced as the bargain takes place as agreed. While the sale of goods in all states except Louisiana is now governed by a state statute, the Uniform Commercial Code, the same concepts as carry forward. A contract and its terms are agreed before or at the time of the sale. The problem with the Shrink Wrap License is that the retail software sale is over and done with before the customer is presented with the one-sided terms of the Shrink Wrap license. After the sale is already made, it is too late to try to impose adverse terms.

Similarly, Raymond T. Nimmer's excellent textbook, *The Law of Computer Technology*, notes that "The attempt to alter the expectations of the common purchaser by virtue of a printed form included with the product package is unlikely to be successful."

How about the specific shrink-wrap license limitation against disassembly and reverse engineering? Two important cases have held that shrink-wrap or (at most) open license agreements cannot be used to

outlaw reverse engineering. Both Landau's book and Nimmer's discusses the important case of *Taun v. Quaid* 198 1988. The state of Louisiana had enacted special legislation to validate various aspects of shrink wrap licenses, including the restriction on reverse engineering. Vault, an Oklahoma corporation, took Quaid, a Canadian corporation, to court in Louisiana to try to take advantage of this exceptional law. Unfortunately for Vault but fortunately for those who think that disassembly is an important consumer right, the court ruled that the Louisiana statute was preempted by federal law. A sensible Louisiana statute has been repealed.

So Microsoft's screen wrap license limitation against disassembly probably isn't worth the paper it's printed on.

How about the law of trade secrets? To begin with, reverse engineering is actually one of the few *legitimate* ways to discover a trade secret. The Uniform Trade Secrets Act (UTSA), adopted in the mid-1980s by almost all states, says explicitly that discovery through reverse engineering is a proper means of gaining access to most patented trade secrets. Choosing one of the many books on intellectual property more or less at random, we find Roger E. Schechter, *Unfair Trade Practices and Intellectual Property*, pp. 135–136 (italics added):

> REVERSE ENGINEERING IS NOT IMPROPER MEANS
>
> Many products are manufactured pursuant to plans or with technologies that are trade secrets and that could be, to the public at large. In some cases the method (and the nature of those items) may be discovered by careful study of the product. Typical methods of discovery include taking the product apart and performing experiments on it. The process of analysis is usually called "reverse engineering." *Nonetheless, the law holds that one who acquires a trade secret by reverse engineering is not an improper means of acquiring a trade secret.* Risk of discovery by reverse engineering is a risk that a firm takes when it chooses to rely on trade secret protection for a valuable commercial asset. Note that a trade secrets patent protects not a new device or manufacturing process, it is protected against reverse engineering. This is one of the most important differences between patent and trade secret protection.

Given that MS-DOS is not patented (its two patent numbers, 4,955,066 and 5,109,433, are the front of all Microsoft manuals) and is a form of data compression as used on every PC in Microsoft's hometown, and that all secrets to be quite straightforward. As far as trade secrets is concerned, reverse engineering is okay. The rationale here is that trade secret law is basically about the loyalty of employees or others who receive important business information in confidence. You violate trade secret law by committing industrial or corporate espionage, by breach of trust. One does not violate anyone's trust by disassembling a product purchased on the open market.

So far, the shrink-wrap license statement against disassembling, screen verbiage, and trade secrets are void. Disassembly works. What about the fact that MS-DOS is copyrighted? Does copyright law permit us to study how DOS works internally and then build products based on this newfound knowledge? For example, how can we duplicate Microsoft's copyright to figure out how DOS preloads DBLSPACE.BIN in MS-DOS 6.0 and then write a replacement for DBLSPACE.BIN that supports the same interface?

Disassembly is sometimes regarded as a form of copying—translating from one medium to another or one language to another—and therefore as possible copyright infringement. However, disassembly for the purposes of achieving compatibility is generally regarded as fair use. An important decision by the Court of Appeals in the Ninth Circuit in *Sega v. Accolade*, August 1992, overturning a lower court's opinion, held that Accolade's use of know-how reverse engineered from the Sega Genesis system did not violate Sega's copyright and constituted fair use. According to the court (as quoted in *UNIX Review*, May 1993),

> We could do that were disassembly is the only way to gain access to the ideas and functional elements embodied in a copyrighted computer program and where there is a

> legal basis cleared for seeking such access; disassembly is a fair use of the copyrighted work, as a matter of law.

The Sega/Accolade decision was underlined in a comment in *Microprocessor Report* (December 9, 1992): "For the first time, we can breathe a deep sigh of relief. No longer are we advising copyright owners to be secretive and refusing to understand the parameters of a undocumented [or 21 cal."

Naturally, several members of the industry breathed a sigh of relief on hearing the appeals court's ruling. Except for a group calling itself the Business Equipment Manufacturers, which includes IBM, Intel, and Microsoft, is seeking stronger protection against reverse engineering. Arguing for greater protection against reverse engineering is the so-called American Committee for Interoperable Systems, which includes Sun Microsystems, Amdahl, and Cups & Technologies (see "Reverse Engineering Reversals," *Upside*, May 1993).

Disassembly is the process of achieving compatibility is okay, and this is the way is also the case under attack from the DOS's increasingly software protection. How about this book's appendix of disassembly listings? Have we violated Microsoft's copyright by reproducing several chunks of code from MS DOS and Windows in this book?

Again, the courts have ruled that computer programs are considered to be "literary works." Moreover, a long-standing notion that a compiled program without its source code, merits being called another work of "literary work" means anything at all in the context of computer software, it would seem to the possible for *literary criticism*. Our discussion of brief excerpts from disassembly listings would clearly be considered fair use, which is one of the oldest forms of fair use (see William S. Strong, *The Copyright Book*, 4th edition, Chapter 8).

Remember that Undocumented DOS and this chapter are based on DEBUG, a tool which Microsoft includes with every copy of MS DOS. Microsoft has made no effort to secure MS DOS against disassembly; a program like DEBUG is able to trace out an INT 21h or INT 2Fh call!

Use the Source, Luke!

Is there any alternative to disassembly? One alternative is, of course, to rely entirely on the vendor's documentation. But to assess whether this documentation is an accurate reflection of the actual software. But as the saying probably goes around the bush now, relying on vendor documentation has as many risks as does relying on undocumented behavior that has been discovered through disassembly.

Depending on what you are interested in, there may be another better alternative to disassembly: source code.

For example, programmers' questions sometimes aren't really about how the operating system behaves in a certain circumstance but more about what their compiler's run-time library (RTL) does. There's probably no other single topic that programmers about the difference between a "DOS" int 21h and a DOS function call. Programmers often call the DOS Set Handle Count function (INT 21h AH=67h) and wonder why it doesn't work. Other functions still have C equivalents such as the case created up by a simple call to the RTL source code. Both Microsoft C and Borland C++ come with RTL source code.

Sometimes rather than having specific questions about MS DOS, programmers are just curious about how operating systems work in general. In this case, the best approach is probably to study one of the several excellent books available on the design and implementation of UNIX. Some of these are Bach's *Design of the UNIX Operating System* and Andleigh's *UNIX System Architecture*; prospective Linux developers should look at Beck's *Linux Kernel Internals*. Another wonderful *Operating System Design: The XINU Approach*, comes with complete source code for a UNIX workalikes. Despite the numerous differences between DOS and UNIX, these books should be required reading for anyone planning to delve into DOS internals.

DOS's handling of resources, processes, files, devices, and so on can often best be understood by contrasting it with a design and implementation of a well understood system such as UNIX.

For a more specific DOS approach to operating system design and implementation another alternative to disassembly of MS DOS is to examine the source code that is available for several DOS workalikes. Tribble Ted DOS from Gaston Software, Redmond WA, has Steve Jones's superb documentation on DOS internals. For an excellent discussion of writing a fully resident DOS, see Steve's article "DOS Meets Real Time" in the February 1992 *Embedded Systems Programming*. General Software's Embed SDK and Device Driver SDK come with complete source code in C for versions of DOS such as CHKDSK, FORMAT, DISKCOMP, ROM DOS 5 from Datalight, Arlington WA is also available with source code.

Last but not least, Mike Podanoffsky (mikep@world.std.com) has written RxDOS, an inexpensive DOS available with all its commented assembly language source code. Podanoffsky is currently writing a full-length book on RxDOS, *Undocumented DOS: A Programmer's Guide to Reserved MS-DOS Functions and Data Structures*, which will be available in 1994. While obviously not identical to the MS DOS source, this source code may be more than adequate for your needs. For example, Figure 6-23 shows the implementation of INT 21h functions 50h, 51h, and 52h from RXDOS.ASM.

Figure 6-23: RxDOS implementation of INT 21h AH=50h, 51h, and 52h

```
        ;*****************************************************************
        ;  50h Set PSP Address                                           *
        ;                                                                *
        ;  bx       contains PSP address to use                          *
        ;*****************************************************************
_SetPSPAddress
        mov word ptr [  RxDOS_CurrentPSP ], bx    , Seg Pointer to current PSP
        ret

        ;*****************************************************************
        ;  51h Get PSP Address                                           *
        ;                                                                *
        ;  bx       contains PSP address to use                          *
        ;*****************************************************************
_GetPSPAddress
        mov bx, word ptr [ _RxDOS_CurrentPSP ]  , Seg Pointer of current PSP
        RetCallersStackFrame es, si
        mov word ptr es:[ _BX  ][ si ], bx
        ret

        ;*****************************************************************
        ;  52h Get Dos Data Table Pointer                                *
        ;                                                                *
        ;  es bx returns pointer to dos device parameter block           *
        ;  -- DOS Undocumented Feature                                   *
        ;*****************************************************************
_GetDosDataTablePtr
        RetCallersStackFrame es, si
        mov word ptr es:[ _ExtraSegment ][ si ], ds
        mov word ptr es [ _BX ][ si ], offset _RxDOS_pDPB
        clc
        ret
```

There are no big surprises here—really how else could Get and Set PSP be implemented, anyway—but we can see that RxDOS creates reflects MS DOS and that having this code earlier in this chapter might have saved us a lot of trouble.

More interesting is Figure 6-24, which shows the RxDOS implementation of Int 21h, the MS DOS implementation of which was shown in Figure 6-20. The RxDOS code provides a useful guide to MS DOS disassembly.

Figure 6-24: RxDOS implementation of INT 21h AH=42h (lseek)

```
;*****************************************************************
;  42h Lseek (Move) File Pointer                                 *
;*****************************************************************
;  al      move method                                           *
;  bx      handle                                                *
;  cx:dx   distance to move pointer                              *
;*****************************************************************
MoveFilePointer:
        Entry
        def _method, ax
        def _handle, bx
        ddef _moveDistance, cx, dx
        ddef _newPosition

        mov ax, bx                          ; handle
        call MapAppToSysHandles             ; map to internal handle info
        call FindSFTbyHandle                ; get corresponding SFT (es: di )
        jc _moveFilePointer_36              ; if could not find -->

        getdarg cx, dx, _moveDistance
        mov ax, word ptr [ _method ][ bp ]
        Goto SEEK_BEG,   _moveFilePointer_beg
        Goto SEEK_CUR,   _moveFilePointer_cur
        Goto SEEK_END,   _moveFilePointer_end
        SetError -1,     _moveFilePointer_36

;
;  seek from end
;
_moveFilePointer_end
        add dx, word ptr es [ sftFileSize  _low  ][ di ]
        adc cx, word ptr es [ sftFileSize. _high ][ di ]
        jmp short _moveFilePointer_beg

;
;  seek from current position
;
_moveFilePointer_cur
        add dx, word ptr es [ sftFilePosition  _low  ][ di ]
        adc cx, word ptr es [ sftFilePosition  _high ][ di ]
    ;   jmp short _moveFilePointer_beg

;
;  seek from beginning
;
_moveFilePointer_beg
        mov word ptr es [ sftFilePosition. _low  ][ di ], dx
        mov word ptr es [ sftFilePosition  _high ][ di ], cx

;
;  Return
;
_moveFilePointer_36
        RetCallersStackFrame ds, bx
        mov word ptr [ _AX ][ bx ], dx
        mov word ptr [ _DX ][ bx ], cx
        Return
```

If you want a disassembly of genuine MS DOS but don't want to DIY, do it yourself, and for some reason you don't like my pre-built disassembly of DOS 1.1 or 2.1, Information Modes (Denton TX) sells a couple of disassemblers. Users of these early versions of DOS. Imodes used the information gleaned from its long-ago disassembly project as part of its well-known product, The 525 Network "Skeptical. We make believers. Over 15,000 sold!" For example, Figure 6-25 shows Imodes' rendition of the Get and Set PSP functions from DI ASM, a disassembly dated April 1987. It is an inter-

esting reflection on the state of knowledge about DOS internals at the time that function 52h is labelled "get device driver list".

Figure 6-25: Imodes Disassembly of DOS 2.1 Set and Get PSP

```
;.............................. Set current PSP ............................ Fn 50
L1006:
  MOV CS:L0191,BX             ;current PSP seg
  RET_NEAR

;.............................. Get current PSP ............................ Fn 51
L100C:
  CALL LOC1A                  ;ds:si--> user's stack
  PUSH CS:L0191               ;
  POP [SI+2]                  ;return in bx
  RET_NEAR
```

Figure 6-26 shows the Imodes interpretation of the lseek function from DOS 2.1, which you can compare against the MS DOS 6.0 disassembly in Figure 6-20 and the RxDOS implementation in Figure 6-24.

Figure 6-26: Imodes Disassembly of DOS 2.1 INT 21h AH=42h (lseek)

```
;..... ..          .        Lseek (handle)      .       .      .  .. Fn 42
                            ;bx   handle
                            ;cx_dx = bx_low dword offset
                            ;al   seek mode,  0 - from file start
                            ;                 1 - from current position
                            ;                 2 - from file end
                            ;return  cy=0, dx_ax = new position (from start)
                            ;     - or -
                            ;return, cy=1, ax = 1 - invalid function (mode)
                            ;                   6 - invalid handle
L3BD5:
  CMP AL,3                  ;is method in range 0..2 ?
  JC L3BDD                  ;no:      yes-->
  MOV AL,1                  ;err = invalid function
L3BDB:
  JMP SHORT L3BD3           ;doa error return
L3BDD:
  PUSH SS
  POP DS
  CALL L38FB                ;with bx=handle, get handle defn
  PUSH ES
  POP DS
  JC L3BD1                  ;if handle bad--> ret, invalid handle
  TEST BYTE PTR [DI+18h],80h ;is char device?
  JZ L3BF2                  ;yes:   no-->
  XOR AX,AX                 ;record = 0 always
  XOR DX,DX
  JMP SHORT L3C08           ;--> set random record fields
L3BF2:
  DEC AL                    ;is method 0, from file start ?
  JL L3C05                  ;no    yes-->
  DEC AL                    ;is method 1, from current position ?
  JL L3C18                  ;no.   yes >
;. . . . . . . . . . . . . . method 2, from end of file
  XCHG DX,AX                ;ax = LSWord
  XCHG DX,CX                ;dx = MSWord
  ADD AX,[DI+13h]           ;add fcb's file size
  ADC DX,[DI+15h]           ;
  JMP SHORT L3C08           ;--> set fields
```

```
;. . . . . method 0, from start of file
L3cDS:
  XCHG DX,AX                    ;ax = LSWord
  XCHG DX,CX                    ;dx   MSWord
```

As with the PSP functions, this disassembly of Int 2Ch in DOS 2.1 bears many similarities to the disassembly of Int 2Ch in DOS 6.0. On the other hand, the DOS 2.1 version does not do Windows and doesn't contain any network redirector code.

Microsoft's DOS OEM Adaptation Kit (OAK)

But perhaps you care deeply and desperately about getting the genuine article: commented source code from Microsoft for MS-DOS v5.0 and higher. Microsoft does not publicize the product a great deal, but Microsoft will sell you an OEM Adaptation Kit on signing a license agreement. Microsoft's OAK comes on an odd-ball formatted tape cartridge, but a version on normal PC diskettes is available from Annabooks, San Diego CA.

The contents of the OAK are Microsoft confidential, so unfortunately we cannot reproduce any of it here, but we can give you some idea of its contents:

```
\DOS50OAK
    \BIOS
        msbio1.asm
        msbio2.asm
        sysinit1.asm
        sysinit2.asm

    \BOOT
        msboot.asm

    \CMD
        \COMMAND
         FORMAT
         MODE

    \DEV
        \ANSI
        \HIMEM

    \DOS
        fat.obj
        getset.obj
        handle.obj
        msdisp.obj

    \H
        cds.h
        dpb.h
        sysvar.h

    \INC
        arena.inc
        bpb.inc
        mult.inc
        pdb.inc
        sysvar.inc
        win386.inc
        wpatch.inc
        .
```

As you can see from this very partial directory tree, Microsoft supplies some components of the OAK in ASM source code form, and others are supplied as OBJ files. The idea, of course, is that the OEM will change parts of IO.SYS but not MSDOS.SYS, so IO.SYS comes with source, but MSDOS.SYS

comes only with OBJ files. Having OBJ files is almost as good as having source code, though, since OBJ files contain names for functions and variables. An OBJ disassembler such as WDISASM included with Watcom C can typically regenerate the source code, missing only comments which are probably out of date and misleading anyway.

Examination of the OAK's contents mostly confirms what has been known for many years as a result of reverse engineering. However, it is sometimes interesting to know the actual names for undocumented functions as they appear in Microsoft's source code. For example, the undocumented structure generally called the List of Lists is called SysVars in the DOS source because the structure is actually intended for use with SYSINIT. INT 21h AH=52h, which returns a pointer to this structure and which is generally called Get List of Lists or GetSysVars, is called GET_SYS_VARS in the DOS source. It turns out that there is little correspondence between the documented names for INT 21h functions and their actual names in the DOS source. For example, AH=1Bh is Get Default Drive Data and AH=1Ch is Get Drive Data in the *MS DOS Programmer's Reference*, but in the code they are called SELECTED_GET and SELECTED_OUT.

Looking over the OAK contents, it seems a shame that source code for MS DOS and Windows isn't more widely available in the same way that it is for IBM PC and IBM AT technical references (for example, IBM *Personal Computer AT* 1985 greatly promoted the development of innovative new software and hardware by publishing complete assembly language listings of the system ROM BIOS). Because Microsoft could promote greater understanding of DOS and Windows by making its source code for these products available. Discussions of the ridiculous as of the year 2000 Consider that just a few years ago, computer companies kept their source code was kept proprietary too. Now, most such companies come with RTL source.

Microsoft did at one point make some attempt at opening up DOS to closer inspection. The original *MS DOS Programmer's Reference* (1986, one of the few books ever to be subject to a recall by the publisher) made an attempt to provide descriptions of each of each DOS function's parameters and purpose, but most of its internal operation was accompanied by a new batch of "How it Works" sections. Here, too, the exercise was flawed. Some functions, such as INT 21h AH=45h "Duplicate File Handle", were described in great detail with the flowchart and example programs while others, such as the undocumented functions such as "call far pointer to DOS function dispatcher", were described only briefly. Microsoft's explanation of the latter was wrong:

> Note: These flowcharts were written for MS DOS Version 3.2. Internal routines are subject to change, so that a flowchart for a previous version of MS DOS may not be the same as the one for the current version. You should take care not to write programs that make use of the specific structure of the functions described here, because they may not be compatible with future versions of DOS. Microsoft guarantees only that the support for the documented functions will be upward compatible, so that you will get back the specified values. How the functions actually work is subject to change.

In addition to these generally vague and misleading flowcharts for each DOS function, the Microsoft developers occasionally went to extremes to document a flowchart for COMMAND.COM.

In the years since the publication of MS DOS internals, With more and more software developers programming for Windows using high-level tools such as Visual C++ and with more and more software developers using the Windows API, it has become less and less necessary and increasingly rare for even power users to know DOS in detail. Hopefully, this chapter has given you some idea of why this is a good thing. Nevertheless, reasoning from first principles is fun. If you don't want to have to think about how DOS works, you don't have to. Just use a high-level C or C++ Win32 API call to read or write a file. But what about understanding how the system really works? You can have only a vague notion of how your own code works.

CHAPTER 7

MS-DOS Resource Management: Memory, Processes, Devices

by Jim Kyle

Resource management is the primary task of an operating system. This chapter concentrates on such features of MS-DOS as memory management, device drivers, memory allocation, and process management. The goal is to discuss these topics with the aid of programs that can be used in your own programming. Examples include a program that loads the CONFIG.SYS file from the DOS command line, and a program that reads the CONFIG.SYS file and shows its contents.

Because MS-DOS is a single-tasking system, the only processor time available is assigned to the foreground process, and the only process that can be loaded into the machine at any time is that process, with full access to all resources.

Operating systems that do not allow multiple processes at the same time are called single-tasking systems. MS-DOS is a single-tasking system, because at least two processes are required for multitasking. The system must contain at least one process that can switch control between two or more programs. A second process is required to run the program that becomes active. Multitasking systems must have a process control block for each process that is running. Each process control block contains all the information about the process that is necessary to suspend it temporarily and then restart it at a later time. Multitasking systems must also have a scheduler, which is the part of the operating system that switches control between processes. Multitasking systems are also called time-sharing systems, because each process is given a slice of time in which to run.

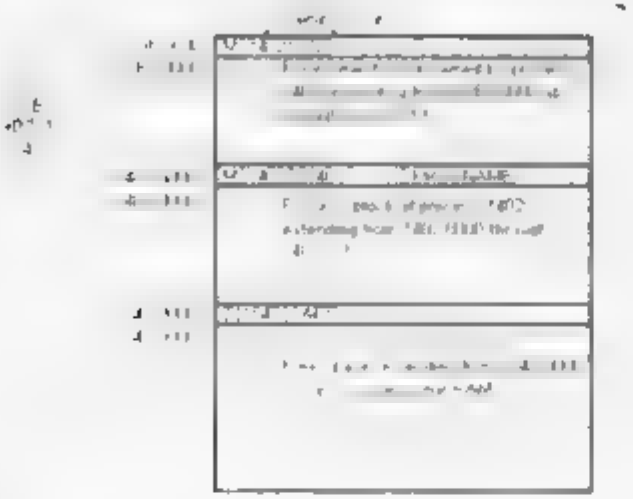
There are special versions of MS-DOS designed for multitasking, such as the Concurrent DOS series of products from Digital Research. Until recently, these products have not had widespread acceptance, but the newer version 6.0 of Concurrent DOS, which is compatible with MS-DOS version 3.3, has had much wider acceptance, and the newer version 6.0

Memory Management

MS-DOS provides several functions for allocating memory. Several other functions, including INT 25h, INT 26h, INT 40h, and INT 13h, are used by the DOS system to control the operation of disk drives. Most of these functions are described in the *Programmer's Reference* manuals listed in the bibliography. This section describes how memory is organized and how these functions are used.

The memory structure used by MS-DOS dates back to the earliest microcomputer systems. The memory is divided into blocks called *paragraphs*. Each paragraph is 16 bytes long. Memory is allocated in paragraphs. The first paragraph in memory is numbered 0. The next paragraph is numbered 1, and so on. Each paragraph is called a *segment*. Figure 7-1 shows how an example of this type of memory structure is laid out.

Figure 7-1. Organization of the DOS Memory Arena



The term memory structure is referred to in official documentation and in Ray Duncan's better than official *Advanced MS-DOS Programming* as the memory arena and the MCB that begins each block is called an arena header. Throughout this column, though, we refer to the arena header by the term MCB.

The initial MCB structure is built at system boot time, just after the parsing of CONFIG.SYS directives. This structure starts memory below the DOS data segment because all RAM in that area was assigned earlier in the boot-up procedure and is not subject to reallocation.

Memory Control Blocks

Each block of memory begins with an MCB, which is a single paragraph. That is, the MCB is 16 bytes long and begins at a valid address that is an exact multiple of 16. Memory blocks themselves are also always allocated in whole paragraphs in length. Using paragraph segment addresses makes it possible to refer to a memory block using a 16-bit segment address rather than a full 20-bit address.

Despite the fact that the UNDOC.DOS.H header file, which we provide to supply full documentation of all of the various undocumented structures our sample code deals with, isn't on the companion diskette, Figure 7-2 shows how each MCB is organized.

Figure 7-2. DOS Memory Control Block Structure

```
typedef struct {          /* Memory Control Block entry    */
  BYTE type;              /* 'M'=in chain; 'Z'=at end      */
  WORD owner;             /* PSP of the owner              */
  WORD size;              /* in 16-byte paragraphs         */
  BYTE unused[3],
  BYTE owner_name[8],     /* filename of owner, v4 DOS4    */
  } MCB, far * LPMCB,
```

When a program requests a block of memory with INT 21h function 48h, DOS must find the number of requested paragraphs, plus one more for the MCB. Assuming that a block of memory is available, DOS sets up its first paragraph as an MCB and hands the segment address of the second paragraph back to the program. Let's say you've made this call:

```
mov ah, 48h             ; Allocate Memory Block
mov bx, 1               ; one paragraph
int 21h
jc fail
; AX now holds initial segment of allocated block
```

Let's say AX now holds the value 1234h. This means that an MCB is located at 1233h. What does this MCB look like?

The first byte of every MCB is MCB type, except the last one in the chain is 4Dh, the ASCII code for 'M'. The first MCB's first byte is instead 5Ah, 'Z'. It may only be coincidental that these two letters are the initials of Compaq's pre-architect of the DOS memory manager, Mark Zbikowski. In our example, the field could contain 'M' or 'Z'; I prefer 'M' as it more likes.

Following this byte, we have a 16-bit value in the low-high format. MCB owner, that is, this is the owner of the MCB. This is usually 0000h if the memory block is available for use. Otherwise, it will contain the PID number of the process to which the block has been allocated, the owner process. This information is used to locate free blocks, those where MCB owner is 0, and to release allocated blocks when a process terminates. This PID number is the Program Segment Prefix, see below, of the owner. In our example, this field would hold the PSP of whatever program was the current process when INT 21h function 48h was called.

Following the owner word is another word, MCB size, giving the size in paragraphs of the memory block controlled by this MCB. In our example, this field will be set to 1, indicating that the MCB at 1233h controls only the next paragraph, at 1234h. In other words, this size value does not include the paragraph occupied by the MCB itself. Consequently, it is possible to have a valid MCB that shows a free block with size equal to 0. This appears when all but one paragraph of a previously free block is allocated. Initial size of a free memory block is 9FFFh paragraphs, not the number of bytes. Even though blocks up to 1 048 575 bytes in size, the entire memory space available to real mode DOS is the first megabyte, under DOS.

The fourth byte in the MCB, the high-order byte of the size word, is unused and consists of MS-DOS 5.0 and 6.0. Versions 2.0 and 3.0 of DOS use the MCB's unused bytes. Starting with DOS 4.0 and later versions, the final eight bytes of the MCB, MCB owner name, may contain the base name of the owning program. The name is padded to the right with zeros. If the MCB that controls the memory used by the program's PSP, otherwise, the final eight bytes are ignored.

To find the next MCB in memory, we add 1 to the MCB's own segment address and add the MCB size value to get the segment address of the RAM that immediately follows the MCB. For example, the next MCB in our example is at segment 1234h + 1 + 1, or 1236h. The segment address of the next MCB from example 2 is the next MCB at 1238h. If the segment 1236h contains anything other than 'M' or 'Z', the MCB chain has been corrupted and no further operations are possible.

The first MCB in memory is created by the DOS kernel when DOS loads. The segment of this MCB contains the memory allocated by the DOS device driver HIMEM.SYS. This is the segment of the extended memory version of DOS that I have been using (0100h), for the reason that I have not yet learned about, however.

The final MCB is created by the 'Z' in its first byte and in normal 640K system generates a next MCB at segment 9FFFh. However, this address should not be used because the 'Z' value indicates the last MCB in memory. Under DOS 5.0 or with early versions when using a third-party memory management system (QEMM or 386MAX), it is possible to enable Upper Memory Blocks. When this is done, the MCB chain may extend past segment 9FFFh, up to the point that ROM BIOS is found. We look at this later in a separate section.

In DOS 4.x and later versions, DOS data segment memory blocks, that is, the RAM that DOS retains for its own use, are not allocated using the List of Lists as described later in this chapter. Instead, DOS creates subsegments. Each subsegment has its own variation of the standard MCB. However, the MCB created MCB chain for the last segment includes the entire memory space of all of the subsegments which appear before the MCB chain.

...ocks subsegments follows a format similar to but not identical with the MCB layout. The first byte ... 5Ah indicating a signature byte. The word at byte 1 is not the owner. Instead, it is the actual segment ... controlled by the block. The word at byte 3 is the size in paragraphs of the con... Byte 5 on appears to contain the filename, padded with blanks, of the file from which a driver was loaded.

Table 7-1 shows the codes used in these subsegment control blocks.

Table 7-1 Codes Used in Subsegment Control Blocks

Code	Directive Meaning Device Driver, If Present
E	device driver appendage, if present
I	IFS Installable File System driver, if present
F	FILES= control block storage area (for FILES=)
X	FCBS= control block storage area, if present
C	(BUFFERS= MS-DOS workspace for BUFFERS= /X option used)
B	BUFFERS= storage area
L	LASTDRIVE= drive info table storage area
S	STACKS= code and data area
T	Transient area (DOS 5 and later only)

...because the structures in control blocks appear only in the DOS data segment and are meaning... ...ess. Some of the appendages found in device drivers appear to be simple machine-code routines, but the general purpose appears to be manipulation of the MCB-like control blocks. The DOS 4.0 and 4.01 Programmer's Guide, most of the information contained in them is ... separate sections, treats the appendages like DOS structures.

Several data structures are used by the buffer-related code initially by DOS for parsing CONFIG.SYS ... appears to be set up and used by DOS rather than DRVINIT. The addresses are not identical ... the CONFIG.SYS buffer uses K to represent STACKS= values. S apparently ... SETUP. For more information on the CONFIG.SYS limits, see Michael ... "Undocumented CONFIG.SYS Options at Boot Time," *Microsoft Systems Journal*, November 1988, pp. 323-344. A discussion of the exploitation of DOS data structures ...

The HMA and UMBs

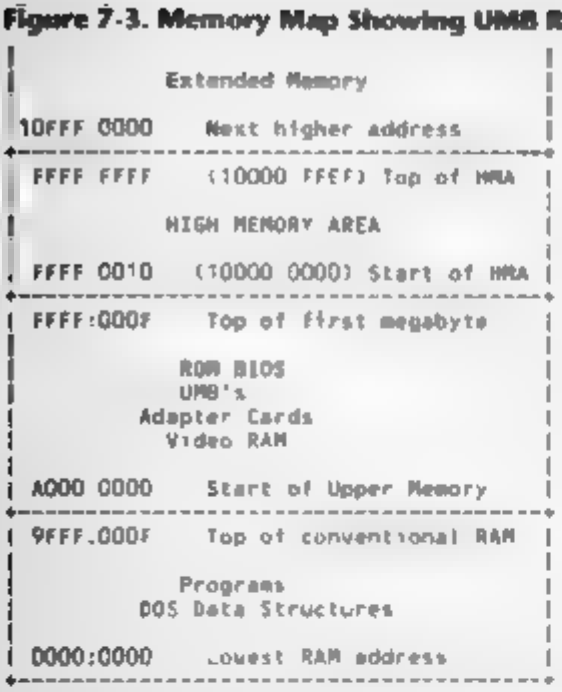
Before we move on to look at the way the MCB chain is followed, let's step back briefly and look at two pow... ...ays that DOS 5.0 can make use of memory in addressing ranges not used by DOS 5.0. These are the High Memory Area and Upper Memory Blocks.

...Most computers with more than 1MB of RAM stop addressing RAM at address 100000H. This address is the start of the 384K hole in the PC's memory map reserved for devices such as video RAM and ROM. Memory-mapped adapter cards and the ROM-BIOS use memory space addressable by even the original 8088. Only programs that use 32-bit segment addresses (FFFF:0000) ...

...When the 80286 processor appeared with the ability to address more than a megabyte of memory, programmers looked for ways to make use of parts of that 384K that were *not* taken up with video and ROM. Extended memory could be used by DOS itself, but new ways to deal with these areas, ... programs such as QEMM and 386MAX provided capabilities to "load programs high" into portions of the 384K that were otherwise unused.

...Microsoft developed its XMS specification that deals with using the High Memory Area and ... Section 4, Microsoft included provisions for allocating the ... Upper Memory Blocks in the 384K adapter-reserved area. With the release of DOS 5.0, allocation of UMBs was officially recognized and documented. Figure 7-3 is a ... map showing where these areas fit with respect to conventional RAM.

Figure 7-3. Memory Map Showing UMB Region and HMA



Making Use of UMBs

To make use of Upper Memory Blocks it's necessary to include a special command DOS=UMB in CONFIG.SYS to enable them. You must also include EMM386.EXE with its option switch RAM or NOEMS or some other memory manager that's a UMB provider to take its place. Some third-party memory managers do not support the DOS=UMB line; check your manual for details.

With these preparations out of the way, all you do is use the internal command LOADHIGH (or its alias LH) preceding your normal program command line. This command-load prefix tells the command interpreter to link the UMB memory chain into the normal conventional RAM MCB chain. The command interpreter also sets the allocation strategy so that DOS searches the UMBs first when looking for space to load your program into. If DOS cannot find enough space in Upper Memory, your conventional RAM will be used with no error or warning message. When your program returns to DOS, the allocation strategy is returned to its original state and the UMB chain is unhooked from the conventional MCB linkage.

The DOS actions we've just described are documented in the *Programmer's Reference for MS DOS 5.0*; the method by which LOADHIGH is implemented, however, has not been. The simple INTRSPY script in Figure 7-4 provides a sequence of events.

Figure 7-4. Organization of the DOS Memory Arena

```
; LOADHIGH.SCR
intercept 21h
    on_entry
        output  "I21 at " cs ":" ip ", AX=" AX ":"
    function 0Ah
        on_entry
            sameline "Buffered Input to " ds ":" dx
    function 25h
        on_entry
            sameline "Set INT" al " ==> " ds ":" dx
    function 26h
```

```
    on_entry
        sameline "Create new PSP at " dx
function 30h
    on_entry
        sameline "Get version, flag = " al "  "
    on_exit
        sameline "Ver " al "." ah ", OEM=" bh
function 35h
    on_exit
        sameline "INT" al " adr is " es ":" bx
function 37h
    on_exit
        sameline "Switchar is " dl
function 48h
    on_entry
        sameline "ALLOC " bx "h paras"
    on_exit
        if (cflag =1)
            sameline " FAIL (" ax "), only " bx "h available"
        if (cflag==0)
            sameline " returned seg " ax "h"
function 49h
    on_entry sameline "FREE seg " es "h"
    on_exit if (cflag==1) sameline " denied (" ax "h)"
function 4ah
    on_entry
        sameline "REALLOC seg " es "h to " bx "h paras"
    on_exit
        if (cflag==1)
            sameline " FAIL (" ax "h), only " bx "h available"
function 4bh
    on_entry sameline "Loading " (ds dx->byte,asciz,64)
    on_exit  output "---ret from child process---"
function 50h on_entry sameline "Set PSP, " BX
function 51h on_exit sameline "Get PSP  " BX
function 58h
  subfunction 00h
    on_entry
        sameline "Get Allocation Strategy"
    on_exit
        sameline " returned " ax
  subfunction 01h
    on_entry
        sameline "Set Allocation Strategy to  " bx
    on_exit
        if (cflag==1)
            sameline " FAILED (" ax "h)"
  subfunction 02h
    on_entry
        sameline "Get UMB Link"
    on_exit
        sameline " returned " al
  subfunction 03h
    on_entry sameline "Link/Unlink UMB to MCBs: " bx
    on_exit
        if (cflag==1)
            sameline " FAILED (" ax "h)"
```

When this script compiles and runs under EMM386 and COMMAND.COM, here's the essential part of the resulting report (the command traced was "LOADHIGH DIDIT" (DIDIT.COM is a tiny .COM file that simply outputs one line and terminates):

```
121 at 9672:59E4, AX=5800: Get Allocation Strategy returned 0000
121 at 9672:59EB, AX=5802: Get UMB Link returned 00
```

```
121 at 9672 596F, AX 5800  Get Allocation Strategy returned 0000
121 at 9672 597A, AX 5801  Set Allocation Strategy to 0080
121 at 9672 5983, AX 5803  Link/Unlink UMB to MCBs  0001
121 at 9672 29FF, AX 4903  FREE seg 1A0Dh
121 at 0B40 01DC, AX 4B00  Loading  D:\WDOS2\ISPY\DIDIT.COM
121 at C0E8 0107, AX 0900
---ret from child process---
121 at FFFF B80D, AX 5800  Get Allocation Strategy returned 0080
121 at FFFF B81E, AX 5801  Set Allocation Strategy to 0000
121 at FFFF B829, AX 5803  Link/Unlink UMB to MCBs  0000
```

You can see that the first call to function 58h came from the transient portion of COMMAND.COM immediately after the EXEC call. With the UMBs again linked and the strategy set to allocate space in the UMA rather than conventional memory, the resident portion of COMMAND.COM then invokes the DOS load-and-execute function (4B00h) that invoked the DOS loader.

The second interrupt call to function 09h from segment C0E8h is the single line report sent by DIDIT.COM. The trace confirms that the program actually did load into the UMB. CS:IP was C0E8:0100 — the first byte of memory above A000h. DIDIT then terminated, returning control to the EMA at segment 01EE. There, COMMAND.COM reset the strategy to normal first-fit and DOS removed the UMA region link, completing the LOADFIRST sequence of events.

The High Memory Area

Unlike UMBs, the High Memory Area can be used only with an 80286 or later processor. Its operation depends on the CPU having more than 20 address bits. The original 8088-based systems had only 20 address lines to work with. If you tried to address a byte at FFFF:0020, for example, the CPU would perform the segment and offset calculation to arrive at an absolute address of 100000h. That however requires 21 bits, not 20. The system simply ignored the excess bit so that an address of this sort appeared instead to be 00000:0000.

When the 80286 appeared with its 24 address bits, the wraparound stopped functioning automatically. So many programs depended on the prior operation, though, that system designers added hardware for the express purpose of making it continue to happen. Of course, this added circuitry had to be capable of being switched in or out in order to run 286 operating systems with 24-bit mode.

What was referred to as the "magic 21st bit" is that bit that becomes possible to address $20: 64K to 128K. It is the first byte of EMA above the 1 megabyte mark without having to switch the processor out of real mode. By convention, it is addressed FFFF:0010 and, depending on the computer, it may or may not be taking place. Programs can load the first 64K to 65,520 bytes of extended RAM the same as conventional RAM.

What specifically have been termed the High Memory Area (HMA) and one of HIMEM.SYS's purposes is to control access to the HMA. But the XMS specification and the DOS 5.0 *Programmer Reference* do not refer to the HMA, but both refer to memory at critical points. Here's the way it really works:

For reasons of compatibility, it is vital that the A20 line, which governs access to the HMA, is turned off when a program is loaded into RAM. DOS is loaded high with the DOS HIGH command, the A20 line is turned on. Access to it can be controlled by each invocation of a DOS service. In fact, once the machine is in protected mode, it must be. Since the loader executes DOS repeatedly in the course of loading a program, it must have access to RAM, the A20 line might as well have been turned off when CONFIG.SYS processed the DOS=HIGH command. You can verify this using DEBUG. Just issue the command g=10:100 (or g=10:0100 if you wish). Then switch the HIMA display on the screen. You can scroll through the whole thing by using repeated "d" commands.

Because the A20 line causes problems with programs that expect wraparound to occur, it is, of course, disabled by the unpacking routine. Microsoft, however, likes to gratuitously embed files with any file that will use EXEPACK to reduce its size. According to Phillip G. Krause, author of the shareware program CONMEM UMB maintenance utility and a veteran in the DOS Expert Developers Forum

[illegible] "Packed file corrupt" error message that began appearing everywhere shortly after the introduction of DOS 5.0 is directly due to the fact that the A20 line is enabled, and the original unpacking routines depended on the segment wraparound effect to properly expand the compressed files.

Specifically, the packing technique used by EXEPACK is a form of run length encoding, the expansion method of which involves moving the packed copy of the program up in memory so that its end is at the highest address the program can use, working backward toward the front of the program. Each time the unpacking routine finds a run-length count code, it calculates a target address for the program's first byte, and then copies the next byte the appropriate number of times. All bytes from the start of the program up to the count code are then moved back to their original target address, and the repeated run is inserted at the appropriate location. The original version of the unpacker calculated the offset of the new target address by adding the count (a 32-bit long) to the current address in 20-bit form. When segment wraparound is in effect, the final calculation produces a 20-bit result of 00000h, which is how it knows that the expansion was successful. Otherwise, when the program happens to be located in the first 64K of the 1Mb address space, the final result wraps into the High Memory area, which causes the "corrupt" message to be displayed. Once the problem was identified, of course, Microsoft fixed it. Data-compression routines and versions of the linkers produced since mid-1988 or so don't have this problem. Most popular packages, though, were built with the older linkers, so the error may be widespread for some time to come. In fact, I stopped using Lotek to the surface during final testing of DOS 6.0, because some new system programs were linked with a recent copy of the linker!

For more on DOS XMI bugs and fixes, see the HMA, see Chapter 1, and the appendix entries for INT 2Fh AX = 4A02h and 4A02h.

How To Find the Start of the MCB Chain

The key to locating the MCB is in the undocumented DOS List of Lists, whose address is returned by INT 21h Function 52h. Although the List of Lists returned by this function differs from one version of DOS to the next, the MCB pointer's location is one of the very few items that is the same in all DOS versions to date. It's always located two bytes in front of the pointer returned in ES:BX, that is, at ES:[BX-2].

Even though it's actually a pointer to the first MCB, but its segment number, that of the DOS list of lists, is a block allocated earlier, to use it as a pointer, you must provide an offset of 0000.

The following assembly-language code fragment shows how to force the MCB pointer into ES:SI so that it may then be used to retrieve the key bytes, the owner word, and the size word. This code only sets up ES:SI and does not retrieve the data.

```
mov     ah, 52h         ; Get List of Lists
int     21h
mov     ax, es:[bx-2]   ; First MCB Segment Address
mov     es, ax
xor     si, si          ; force offset to be zero

or, to be safe,

xor     bx, bx
mov     es, bx          ; set ES:BX to 0:0
mov     ah, 52h
int     21h
mov     cx, es
or      cx, bx          ; is ES:BX still 0:0?
jz      fail            ; then Function 52h not supported
mov     ax, es:[bx-2]   ; First MCB Segment Address
mov     es, ax
xor     si, si          ; force offset to be zero
fail:
```

The next code segment then retrieves the key byte, the owner word, and the size word, respectively. The code assumes that ES:SI is unchanged from the preceding example.

```
mov     al, es:[si]     ; gets key byte, 'M' or 'Z'
mov     bx, es:[si+1]   ; gets owner word or 0000
mov     cx, es:[si+3]   ; gets size in paragraphs
```

For most applications, the code fragment in Figure 7-5 may be more useful. It can be used in Microsoft C 5.0 and higher, QuickC 2.0 and higher, Borland Turbo C 2.0 and higher, and Borland C++ 2.0 and higher.

Figure 7-5 Get First MCB() Routine

```
#include <dos.h>                    /* use standard header file     */
#include "undocdos.h"               /* use our standard header file */
                                    /* to define MCB structure and  */
                                    /* MK_FP macro (make far ptr).  */

LPMCB Get_First_MCB( void )         /* locate first MCB, return ptr */
{ union REGS reg,                   /* REGS, SREGS are defined by   */
  struct SREGS seg;                 /* the DOS.H header file        */
  WORD *tmpp,

  segread( &seg );                  /* set up seg regs              */
  reg.h.ah = 0x52;                  /* get List of Lists in ES:BX   */
  intdosx( &reg, &reg, &seg );
  tmpp = (WORD far *) MK_FP( seg.es, reg.x.bx - 2 );
  return (LPMCB) MK_FP( *tmpp, 0 );
}
```

Get_First_MCB() is functionally identical to the first assembly language fragment. This function uses the MK_FP() macro to build a 4-byte far pointer value (Microsoft C++ 7 creates the segment and pointer value rather than setting the appropriate registers and INTs). As explained in Chapter 2, you can also use inline assembler or register pseudo-variables if your compiler supports these options.

How To Trace the MCB Chain

Let's look at how to build a program that walks through the MS-DOS MCBs and tells us how RAM is being used. You probably have such a program on your machine. You've used this popular program—MEM—since MS-DOS 4.0 and later. TMAP (Turbo Debugger), MAPMEM (Microsoft Software Tools), and FLDMEM (Borland Turbo Debugger 2.0) However, our version, DMEM, is a good tool for learning how system code is written.

Because each MCB owner PSP is the program that owns the block, we can use this program to trace through all PSPs, showing which programs are resident in memory. When we refer to MCBs controlling PSPs, we only mean that the block of memory controlled by an MCB happens to be a program. To be precise, it is not a program or a process (program in execution) that has been loaded into memory. All DOS processes begin with a 256-byte PSP. The MCB system tracks PSPs and memory in the sense that the MCB's are an access point to memory used by the PSP and by the process itself. For example, a PSP at 0A49 is controlled by an MCB at 0A48. The owner field of the MCB at 0A48 would be 0A49.

Our DMEM program displays the segment number of each MCB, the Program Segment Prefix of its owner, and the size of the MCB in hex paragraphs and decimal bytes. For MCBs that hold actual PSPs, DMEM also displays the segment for the corresponding environment, the ASCII filename of the owner (available in DOS 3.0 and higher), and the program's environment. And any interrupt vectors that point into the block of memory. This program also shows subsegments within the DOS data segment that DOS itself knows about (UMBs).

One fact to note about MCB walkers is that they assume the presence of only one MCB chain. In fact, programs such as 386MAX and QEMM allow memory-resident programs to be loaded high

or creating a secondary MCB chain in high DOS memory. With the advent of UMBs in DOS 5.0, this is the rule rather than the exception. Our UDMEM program shows secondary MCB chains. Figure 7-6 shows what UDMEM's output looks like.

Figure 7-6. Sample of UDMEM Output

```
D:\UDOS2\CHAP7> udmem
Seg     Owner   Size
0253    0008    092A ( 37546)   DOS Data Segment
          Seg  Size Type
          ---- ---- ---------------
          0254 0041 Device Driver (386MAX)
          0296 0015 Device Driver (386LOAD)
          02AC D741 Device Driver (SSTORDRV) [26 F5 FA FE ]
          09EE 0015 Device Driver (386LOAD)
          0A04 005D System File Tables
          0A62 0005 FCBs
          0A68 0020 Buffers
          0A89 0037 CDS Table
          0AC1 00BC Stacks [02 0A 08 0C 0D 0E 70 72 73 74 76 ]
0B7E    0008    0004 (    64)   DOS Code area
0B83    0B84    0010 (   256)   Env at 0B14     chap7 new /pd:\udos2\chap7\udkeys /q
0B94    0BB4    0005 (    80)
0B9A    0B9B    0147 (  5232)   Env at 0B95     /i 2048 /l:20
0CE2    0CF1    000D (   208)
0CF0    0CF1    4CDB (315800)   Env at 0CE3     D:\UTILS\PE2.EXE  chap7.new  /pd:\udos2\chap7\udkeys
                                                /q [30 E5 E6 F7 FF ]
59CC    59DB    000D (   208)
59DA    59DB    0010 (   256)   Env at 0A36
59EB    59FB    000B (   176)
59F7    59FB    1268 ( 75392)   Env at 59EC     D:\UDOS2\CHAP7\UDMEM.EXE  [00 E9 F9 ]
6C60    0000    339E (211424)   free [EC EF F4 ]
9FFF                            End of conventional RAM
        UMB Chain
C800    FFFF    058E ( 22752)   386LOADed Driver [13 15 28 ]
C80F    FFFA    0004 (    64)   386MAX UMB control block
C814    FFFE    0205 (  8272)   386MAX UMB
CF9A    FFFA    0004 (    64)   386MAX UMB control block
CF9F    FFFE    0022 (   544)   386MAX UMB
CFC2    FFFA    0004 (    64)   386MAX UMB control block
CFC7    FFFE    0022 (   544)   386MAX UMB
CFEA    FFFA    0004 (    64)   386MAX UMB control block
CFEF    FFFE    0042 (  1056)   386MAX UMB
D032    FFFA    0004 (    64)   386MAX UMB control block
D037    FFFE    0210 (  8448)   386MAX UMB
D248    FFFA    0004 (    64)   386MAX UMB control block
D249    FFFE    00C0 (  3072)   C:\4DOS\4DOS.COM [2E ]
D30E    FFFA    0004 (    64)   386MAX UMB control block
D313    FFFE    0020 (   512)   386MAX UMB
D334    D33C    0006 (    96)
D33B    D33C    04CD ( 19664)   Env at D8DA     C:\UV\UV.COM [1C ]
D809    D33C    0002 (    32)
D80C    D814    0006 (    96)   [20 21 27 29 ]
D813    D814    01AD (  6864)   Env at D9C2     D:\UTILS\CTRLALT.COM  [08 09 ]
D9C1    D814    0002 (    32)
D9C4    FFFA    0004 (    64)   386MAX UMB control block
D9C9    FFFE    0066 (  1632)   386MAX UMB [22 23 24 2F ]
DA30    FFFA    0004 (    64)   386MAX UMB control block
DA35    FFFE    0020 (   512)   386MAX UMB
DA56    0000    05A8 ( 23168)   free
DFFF    FFFD    1200 ( 73728)   386MAX locked-out area [EB ]
F200    FFFF    0059 (  1424)   386LOADed Driver [1B ]
F25A    0000    05A4 ( 23104)   free
F7FF    FFFD    0400 ( 16384)   386MAX locked-out area
```

```
FC00    FFFF    00AB (  2768)   386LOADed Driver [40 67 ]
FCAE    FCB6    0006 (    96)
FCB5    FCB6    0042 (  1056)   Env at FCF9    C:\4DOS\KSTACK.COM  [16 ]
FCF8    FCB6    0002 (    32)
FCFB    0000    0004 (    64)   free
FD00                           End of UMB Chain
```

To create this sample of output, I shelled out to DOS from within my text editor program (DVC TEDIT.EXE) at address 0C11. The output shows both the normal RAM area below A000:0000 and the Upper Memory Blocks above that point. It also shows how various interrupts are routed to different drivers and programs both above and below the UMB mark. Those references to such interrupts as 1C, EF, and E4 result from the fact that during the boot-up process initialization code uses the top of the interrupt vector area as its stack and never cleans the memory out afterward. These references are not valid.

It is useful to write UDMEM in two stages. First, just print out raw information about DOS memory control blocks. Then, after that simple program is working, write an improved version that displays the NAME filenames of the owners of the MCBs, which gives us a display of all programs resident in memory, including, of course, the UDMEM program itself. Figure 7-7 shows our first version of the UDMEM.EXE program.

Figure 7-7. First Version of UDMEM

```
/*
UDMEM1.C -- walks DOS MCB chain(s): simple version
Andrew Schulman and Jim Kyle, July 1990
        revised by Jim Kyle, August 1992, March 1993
*/
#include <stdlib.h>             /* needed by MSC only   */
#include <stdio.h>
#include <dos.h>
#include "undocdos.h"
void fail(char *s) { puts(s); exit(1); }

LPMCB get_mcb(void)
{
    _ASM mov ah, 52h
    _ASM int 21h
    _ASM mov dx, es:[bx-2]
    _ASM xor ax, ax
    /* in both Microsoft C and Turbo C, far* returned in DX:AX */
}

void display(LPMCB mcb)
{
    char buf[80];
    sprintf(buf, "%04X    %04X    %04X (%6lu)",
        FP_SEG(mcb), mcb->owner, mcb->size, (long) mcb->size << 4);
    if (! mcb->owner)
        strcat(buf, "   free");
    puts(buf);
}

void walk(LPMCB mcb)
{
    printf("Seg     Owner   Size\n");
    for (;;)
        switch (mcb->type)
        {
            case 'M' :          /* Mark : belongs to MCB chain  */
                display(mcb);
                mcb = (LPMCB)MK_FP(FP_SEG(mcb) + mcb->size + 1, 0);
                break;
```

```
            case 'Z' :          /* Zbikowski : end of MCB chain */
                display(mcb);
                printf("%04X\n", FP_SEG(mcb) + mcb->size + 1);
                return;
            default :
                fail("error in MCB chain");
        }
}
main(int argc, char *argv[])
{
    walk(get_mcb());
    //could walk UMB chain here too
}
```

A DMI MCB walker program displays the raw MCB chain and makes no attempt to connect to any upper memory blocks that may be present. The function get_mcb(), written with the Borland C++ inline assembler, returns a far pointer to the first MCB. Even though we're calling undocumented DOS function 52h here, we don't need to worry about different DOS versions, as this is supported on all DOS versions since 2.0. In fact, this function is even supported in the DOS compatibility boxes of OS/2 and Windows NT, see Chapter 4. The start of the MCB chain is passed to the function walk(), which goes into a loop, displaying an MCB and moving to the next MCB until the end of the chain is encountered. The MCB is displayed using the function display(). The output of this program looks like this:

```
Seg     Owner   Size
09F3    0008    03E1 ( 15888)
0DD5    0DD6    0003 (   3376)
0EA9    0000    0003 (   48)     free
0EAD    0DD6    0040 (   1024)
0EEE    C0D6    0004 (   64)
0EF3    0FD2    000D (    208)
0FD1    0FD2    1204 ( 73792)
2106    0000    7EF9 (520080)    free
A000
```

MCB Consistency Checks

Now let's make a module out of this. After chopping out main(), it can be linked into other programs and used to check the DOS memory allocation. This is particularly useful when you are trying to locate a trashed MCB chain. Listing 7-8 shows the walk() function turned into mcb_chk(), as shown in Figure 7-8. With it, you can check the MCB chain for consistency before DOS does. The chain is considered valid if the type byte is equal to anything other than 'M' or 'Z'.

Figure 7-8. Routine to Check MCB Chain

```
BOOL mcb_chk(PMCB mcb) /* see UNDOCDOS.H for typedefs  */
{ for (;;)
    if (mcb->type == 'M')
      mcb    (PMCB)MK_FP(FP_SEG(mcb) + mcb->size + 1, 0),
    else
      return (mcb->type == 'Z');
}
```

With mcb_chk(), a program can periodically check the MCB chain with a call such as the following:

```
if (! mcb_chk(get_mcb()))
{
  /* maybe do stack backtrace here, or dump registers */
  puts("Error in MCB chain - prepare for halt...");
  getchar();
}
```

Of course, if mcb_chk does return FALSE then the next time any memory allocation is performed the system will halt with a message such as

```
Memory allocation error
Cannot load COMMAND, system halted
```

DOS memcb performs the same consistency check as mcb_chk except that, if it does find anything other than 'M' or 'Z' DOS has no choice but to halt the system. There seems to be no way that the MCB chain could be reliably repaired. In multitasking 80386 control programs such as DESQview or Windows 386 running real mode MCB's can run in a DOS box (virtual machine) is far less catastrophic. You just throw the virtual machine away and get a new one.

Our minimal MCB walker has one other use. We can use it to reveal a bug in DOS itself. In the entry for INT 21H Function 4Ah Resize Memory Block the appendix notes that "if there is insufficient memory to expand the block as much as requested, the block will be made as large as possible." Don't believe it. Just substitute the version of main() shown in Figure 7-9 for the one provided in Figure 7-7.

Figure 7-9. How To Demonstrate a DOS Bug

```
main(void)
{
  unsigned segm,
  ASM mov ah, 48h                          /* Allocate Memory Block */
  ASM mov bx, 64h                           /* get 100 paragraphs   */
  ASM int 21h
  ASM jc done
  /* ax now holds initial segment of allocated block */
  ASM mov segm, ax
  printf( before   ); display(MK_FP(segm - 1, 0));

  ASM mov ax, segm
  ASM mov es, ax                             * now resize the block */
  ASM mov ah, 4Ah                           /* Resize Memory Block  */
  ASM mov bx, 0FFFFh                /* impossible in real mode      */
  ASM int 21h
  ASM jnc done        /* something badly wrong if  didn't  fail' */
  printf("after:  "); display(MK_FP(segm - 1, 0));
done
  return 0,
}
```

The resulting display shows that all remaining memory has in fact been given to the block even though the call failed:

```
before. 104C    0BEA    0064 (  1600)
after:  104C    0BEA    9A83 (633648)
```

The enormous number of bytes allocated to MCB 104C in the second line shows that even though Function 4Ah returned with the carry flag set indicating an error, the block was still made as large as possible. It's particularly large here because this test was run on a system with QuarterDeck QEMM. This is just one example of a DOS not an undocumented feature on which you should depend. As it stands, it allocations that fail but that nonetheless snarf memory can cause mysterious program behavior.

The way to avoid this is that DOS assigns all free space to the program before discovering that there's not enough, but then fails to restore the original program allocation and put the free space back once the error has been detected.

This example also shows that the display() function can be useful all by itself. Just pass the function an MCB and it displays some information. Given the segment address of a block of memory

example to remember that the MCB is located at the preceding paragraph. If a PSP is, for instance, 1234h as MCB is 1233h. This is why segment-1 rather than segment is used above in the call to displayseg.

A More Detailed UDMEM Program

To provide a more complete display we need to change the display function, hook into any UMB chains that may be present, and add supporting functions.

Some of the relationships between MCB, PSP, and environment can get a little confusing, so we use a few macros that are defined in UNDOC.DOSH:

```
#define MCB_2M_SEG(seg)      ((seg)   1)
#define IS_PSP(mcb)          ((FP_SEG(mcb) + 1 == (mcb)->owner) && \
                              *(WORD far *) MK_FP(FP_SEG(mcb) + 1, 0) == 0x20CD))
#define ENV_2M_PSP(psp_seg) (*(WORD far *) MK_FP(psp_seg, 0x2c)))
```

The MCB_2M_SEG(seg) macro simply converts the PSP segment value to the corresponding MCB segment value. The last, ENV_2M_PSP(seg), grabs the segment address of the environment block from offset 2Ch in the PSP. The IS_PSP macro performs two tests on a segment value to determine whether or not it is a PSP segment. The first test simply verifies that the block owns itself. However, a number of protected-mode programs, such as Windows 3.x and some recent DOS programs, have been observed to create MCBs such that this test is inadequate. Thus if a segment passes the first test, we go on to verify that the first two bytes of the segment are CD 20h, the machine code for INT 20h. All PSPs contain these two bytes at a specific offset that we have can into so far fail the test.

Figure 7-10. New Display Routine

```
void display( PMCB mcb )
{ static FP vect_2e = ( FP ) 0,
  WORD env_seg;
  printf( "%04X    %04X    %04X (%6lu)   ",
          FP_SEG( mcb ), mcb->owner,
          mcb->size, ( long ) mcb->size << 4 );

  if( IS_PSP( mcb ))
    { FP e = env( mcb );                    /* MSC wants lvalue     */
      if( ( env_seg = FP_SEG( e )) != 0 )
        printf( "Env at %04X    ", env_seg );
      else
        printf( "No Env Segment " );
    }

  if( !vect_2e )
    vect_2e = GETVECT( 0x2e );              /* do just once         */

/* INT 2Eh be owned by master COMMAND.COM (or other shell) */
  if( belongs( vect_2e, FP_SEG( mcb ), mcb->size ))
    printf( "%s ", getenv( "COMSPEC" ));
  else
    switch( mcb->owner )                    /* decode special stuff */
      {
      case 0 :
        printf( "free " );
        break;
      case 6 :
        printf( "DR-DOS XMS UMB " );
        break;
      case 7 :
        printf( "DR-DOS hole   " );
        break;
      case 8 :
        printf( "DOS " );
        display_subsegs( mcb, mcb->size );
```

```
        return;                          /* display_subsegs cleans up */
      case 0xFFFA
        printf( "386MAX UMB control block " ),
        break;
      case 0xFFFD
        printf( "386MAX locked-out area " );
        break;
      case 0xFFFE
        printf( "386MAX UMB " ),
        break;
      case 0xFFFF
        printf( "386LOADed Driver " ),
        break;
      }
  display_progname( mcb ),               // moved from original location
  if( IS_PSP( mcb ))
    display_cmdline( mcb ),
  display_vectors( mcb );
  printf( "\n" );
}
```

The new display (Figure 7-10) calls env (Figure 7-11) to find out if the MCB contains the PSP of its owner and therefore has an associated environment block.

Figure 7-11. Environment-Locating Routine

```
char far * env( LPMCB mcb )
{ char far * e,
  WORD env_mcb,
  WORD env_owner,

  /*  if the MCB owner is one more than the MCB segment then
   *      psp  = MCB owner
   *      env_seg    make far_pointer(psp, 2Ch)
   *      e  = make far_pointer(env_seg, 0)
   *  else
   *      return NULL
   */
  if( IS_PSP( mcb ))
    e = MK_FP( ENV_FM_PSP( mcb->owner ), 0 ),
  else
    return ( char far *) 0,

  /* Does this environment really belong to this PSP? An
   * environment is just another memory block, so its MCB is
   * located in the preceding paragraph.  Make sure the env
   * MCB's owner is equal to the PSP whose environment this
   * supposedly is! Thanks to Rob Adams of Phar Lap Software
   * for pointing out the need for this check, this is a
   * good example of the sort of consistency check one must
   * do when working with undocumented DOS.
   *
   * Note that with DOS5, this test had to be changed to just
   * reject free MCBs, because 386MAX added special codes in
   * the owner field that caused our original test to fail!
   */
  env_mcb = MCB_FM_SEG( FP_SEG( e ));
  env_owner = (( MCB far *) MK_FP( env_mcb, 0 ))->owner,
/*return ( env_owner == mcb->owner ) ? e :( char far *) 0; changed! */
  return ( env_owner ) ? e :( char far *) 0;
}
```

The env function uses the IS_PSP macro to verify that this MCB is a PSP and that the environment pointer is not NULL. In its original version, env further made sure we didn't pick up a

stray environment for a program that has freed its environment. Usually such programs don't bother to zero out the environment segment number located at offset 2Ch in the PSP. The next-to-last line of this program is the one commented out; was the original test. After Qualitas' 386MAX memory manager began using the owner field of the MCB for other purposes, it was necessary to change this function.

The display_mcb() function interprets the owner field of the MCB to decode all the special values that might appear there. If this shows the block to be the DOS data segment, display calls display_subsegs() (Figure 7-12) to list the subsegments.

Figure 7-12. Decoding DOS Subsegments

```
static BOOL ssdone = FALSE;

void display_subsegs( LPMCB mcb, WORD subsegs )
{ char tmp[ 10 ],
  char far * src;
  int i;
  if( ssdone )                  /* if not first DOS area        */
    { printf( "Code area\n" );
      return;
    }
  printf( "Data Segment\n" );
  if( _osmajor < 4 )            /* subsegments only in V4+      */
    return;

  printf    t  Seg  Size Type \n\t                              \n" ),
  mcb = MK_FP( FP_SEG( mcb ) + 1, 0 );
  while( (int)subsegs > 0 ) /* process each subsegment      */
    { printf( \t   04X  04X   , FP_SEG( mcb ), mcb->size ),
      src   &( mcb->owner_name[ 0 ]), /* copy filename for D, I */
      for(     0, i < 8 && *src > ' '; i++ )
        tmp[ i ]   *src++,
      tmp[    ]   0,
      switch( mcb->type )       /* translate type codes         */
        {
        case 'D' :
          printf(  Device Driver (%s) ", tmp ),
          break,
        case 'E'
          printf( "Device Driver appendage   ),
          break,
        case 'I' :
          printf( "IFS Driver (%s) ", tmp ),
          break,
        case 'F' :
          printf( "System file tables " ),
          break,
        case 'X' ,
          printf( "FCBs " );
          break,
        case 'C'
          printf(  Buffer Workspace   ),
          break,
        case 'B'
          printf  "Buffers   ),
          break,
        case 'L'
          printf  "CDS Table " );
          break,
        case 'S'
          printf  "Stacks " );
          break,
        case 'T'
          printf( "Transient Code " );
```

```
        break;
      default :
        printf( "Unknown subsegment " ),
      }
    displayvectors( mcb ),   /* show vecs for this area      */
    printf( "\n" );
    subsegsz += ( mcb->size + 1 );
    mcb = MK_FP( FP_SEG( mcb ) + mcb->size + 1, 0 );
  }
 asdone = TRUE;
}
```

Next, displaymcb calls displayprogname, which in turn calls progname_fm_psp (Figure 7-13). This useful utility function, given a PSP, tries to return a far pointer to the name of the corresponding program.

Figure 7-13. Obtaining the Program's Name

```
char far * progname_fm_psp( WORD psp )
{ char far * e,
  WORD len,

/* is there an environment? */
  if( ! ( e = env( MK_FP( MCB_FM_SEG( psp ), 0 ))))
    return ( char far *) 0;

/* program name only available in DOS 3+ */
  if( _osmajor >= 3 )
    { do                    /* skip past environment variables      */
        e += ( len = fstrlen( e )) + 1;
      while( len ),
      if( !*e ) /* test for empty env in UMB, created by 386MAX */
        e++;

      /*  e now points to WORD containing number of strings following
       *  environment, check for reasonable value: signed because
       *  could be FFFFh; will normally be 1
       */
      if(( *(( signed far *) e ) >= 1 ) && ( *(( signed far *) e ) < 10 ))
        { e += sizeof( signed );
          if( isalpha( *e ))
            return e,
        }
    }
  return ( char far *) 0,
}

void displayprogname( LPMCB mcb )
{ char far * s,
  if( IS_PSP( mcb ))
    if(( s = progname_fm_psp(( FP_SEG( mcb ) + 1 ))) != 0 )
      printf( "%Fs ", s ),
}
```

If an MCB corresponds to a PSP, IS_PSP is TRUE, displayprogname calls progname_fm_psp, which first verifies that there is an environment. Possibly there is a little too much vertical white space in this program, but any program that traffics in undocumented DOS should certainly be more paranoid than programs that rely only on documented interfaces. In DOS 3+, progname_fm_psp walks past all variables in the environment to find the ASCIIZ pathname of the program owning the environment (see the description of the DOS environment block in the appendix entry for INT 21h Function 26h).

The new version of displaymcb next calls displaymcbline (Figure 7-14).

Figure 7-14 Showing Command Arguments

```
void display_cmdline( LPMCB mcb )
{ /*    psp := MCB owner
  *     cmdline_len := psp[80h]
  *     cmdline := psp[81h]
  *     print cmdline(display width  = cmdline_len)
  */
  int len = *(( BYTE far *) MK_FP( mcb->owner, 0x80 )),
  char far * cmdline = MK_FP( mcb->owner, 0x81 ),
  printf( "%.*Fs ", len, cmdline ),
}
```

Note that display_cmdline uses the C printf mask "%.*Fs" to display a far string, using the maximum length, variable len whose value may be zero. Sometimes garbage is printed by MEM, or by any similar program, because the disk transfer area located inside the PSP overlays the beginning of the environment block.

The simple function belongs (Figure 7-15) determines if an interrupt vector points into the block of code managed by MCB. The BOOL, FP and WORD types are defined in UNDOC DOS.H.

Figure 7-15 Testing Interrupt Vectors

```
BOOL belongs( FP vec, WORD start, WORD size )
{ WORD seg = FP_SEG( vec ) + ( FP_OFF( vec ) >> 4 ),/* normalize */
  return ( seg >= start ) && ( seg <= ( start + size ));
}
```

Finally, display_vectors calls display_vectors() (Figure 7-16) to show any interrupts hooked by the program whose PSP is contained in this MCB. The function finds these hooked interrupts simply by seeing if CS:IP for the interrupt handler falls within this MCB.

Figure 7-16. Showing Interrupt Vectors

```
# ifdef __MSDOS__
#define GETVECT(x)      getvect(x)
#else
#define GETVECT(x)      _dos_getvect(x)
#endif

void display_vectors( LPMCB mcb )
{ static FP * vec = ( FP *) 0;
  WORD vec_seg;
  int i,
  int did_one = 0;
  if ( ! vec )              /* one-time initialization      */
    { if (( vec = calloc( 256, sizeof( void far *))))
        fail ( "insufficient memory" );
      for( i = 0; i < 256; i ++ )
        vec[ i ] = GETVECT( i );
    }
  for( i = 0; i < 256; i ++ )
    if( vec[ i ] && belongs( vec[ i ], FP_SEG( mcb ), mcb->size ))
      { if( ! did_one )
          { did_one ++ ,
            printf( "[ " ),
          }
        printf( "%02X ", i ),
        vec[ i ] = 0;
      }
  if( did_one )
    printf( "]" ),
}
```

In DOS 4.0 and higher some memory resident software can be loaded using the INSTALL statement in CONFIG.SYS. Such programs can show up in the UMBMEM listing as MCBs that aren't associated with any program or which may have hooked interrupt vectors. Note that UMBMEM can display vectors for all MCBs even when there seems to be no associated program. For example, in DOS 4.0 and higher if CONFIG.SYS contains the statement DEVICE=C:\DOS\DOSKEY.COM to load Chris Dunford's DOSKEY command line editor then UMBMEM displays something like the following:

```
0E81    0E82    065F ( 26096)   [1B 21 61 ]
```

Another benefit of using display vectors for all MCBs is that occasionally we find orphaned interrupt vectors that point into free memory:

```
2A2A    0000    7 (482640)          free    [30 F4 F5 FB ]
```

INT 30h is a far jump instruction, not an interrupt vector, but INTs F4h, F5h, and FBh are real interrupt vectors. Let's hope no program invokes them while they're pointing into free memory! Since these vectors are used as the stack during boot up, it's essential that any program that tries to invoke them be certain they have first been set to valid interrupt service routines.

The string length function shown in Figure 7-17 lets us easily get the length of far strings even from a small model program:

Figure 7-17. Determining String Length

```
WORD fstrlen( char far * s )
{
#if defined(_MSC_VER) && (_MSC_VER >= 600)
  return _fstrlen( s );
#else
  WORD len = 0;
  while( *s++ )
    len++;
  return len;
#endif
}
```

In addition to the changes made to the display function, it's also necessary to modify walk, as shown in Figure 7-18, so that it automatically includes any Upper Memory blocks that may be in use:

Figure 7-18. Revised Walk Routine

```
void walk( LPMCB mcb )          /* walks chain displaying data  */
{ printf( "Seg     Owner    Size\n" );
  for( ; ; )
    switch( mcb->type )
      {
      case 'M' :                /* Mark   belongs to MCBchain   */
              display( mcb );
              mcb = MK_FP( FP_SEG( mcb ) + mcb->size + 1, 0 );
              break;

      case 'Z' :                /* Zbikowski : end of MCB chain */
              display( mcb );
              printf( "%04X                                  ",
              FP_SEG( mcb ) + mcb->size + 1 );
              if( FP_SEG( mcb ) < 0xA000 )
                { printf( "End of conventional RAM\n" );
                  mcb = firsthi();     /* try to link to UMB area */
                  if( mcb == ( FP ) 0L )   /* No UMB MCB's found  *
                    return;
```

```
            printf( "        UMB Chain\n" );
          }
        else
          { printf( "End of UMB Chain\n" );
            return;
          }
        break;

    default
        fatal( "error in MCB chain" );
    }
}
```

If UMBs are not set but LOADHI is running from conventional RAM, there are actually two separate MCB chains: the first starts at the end of conventional RAM, while the other is entirely in the upper memory area. If LOADHIGH or DH is used to load UDMEM, the two chains merge automatically.

To add code to deal with the case of two chains, the actions performed when the program detects the "Z" type block are changed. If the current MCB is below the top of conventional RAM (A000h), the program checks the next link to see if it points to the UMB region. Otherwise, the second chain is assumed, and the end has already been encountered.

The function FirstUMB, which scans the link to any UMBs that might be present, is a separate module, shown in Figure 7-19. A simple Pascal calls program linked into the UDMEM program. The function returns NIL if the UMB chain is not located or a far pointer to the first MCB in the chain. The functions FirstUMB and XmsInstalled were written by Kim Kokkonen, president of TurboPower Software, and are used in a number of the TSRCOM utilities. The TSRCOM utilities include MARK and RELEASE, which permit TSRs easily to be unloaded. They are available on CompuServe and on many BBS systems.

Figure 7-19. Finding the UMB Chain

```
{
 * FIRSTMI - utility to locate first UMB address
 *
 *       adapted from:
 *         XMS.PAS - unit of XMS functions
 *         Copyright (c) 1991 Kim Kokkonen, TurboPower Software.
 *         MEMU.PAS - utility unit for TSR Utilities.
 *         Copyright (c) 1991 Kim Kokkonen, TurboPower Software
 *       by Jim Kyle, with permission of Kim Kokkonen.  Thanks, Kim!
 *
 *       These are part of Kim's TSRCOM utility that includes
 *       MARK and RELEASE among others.
 *

#include <dos.h>
#include "undocdos.h"

static BYTE XmsInstalled( void )        /* true if XMS mgr here */
{ ASM mov ah,0x30;
  ASM int 0x21;
  ASM cmp ax,3;
  ASM jae Check2F;
  ASM mov al,0;
  ASM jmp Done;
Check2F:
  ASM mov ax,0x4300;
  ASM int 0x2F;
Done:
  ASM mov ah,0;
}
```

```
static FP XmsControlAddr( void )        /* gets far ptr to code */
{ ASM mov ax,0x4310;
  ASM int 0x2F,
  ASM mov ax,bx,
  ASM mov dx,es,
}

static FP XmsControl;

static BYTE AnyUMB( void )              /* verify that a UMB exists     */
{ ASM mov ah,0x10,
  ASM mov dx,0xFFFF,                    /* force an error return in BL  */
  ASM call dword ptr [XmsControl];
  ASM xor ah,ah;
  ASM mov al,bl,                        /* return error result          */
}

LPMCB FirstMCB( void )
{ WORD  Segment;
  WORD  Size,
  WORD  Mseg,
  BOOL  Done,
  BOOL  Invalid,
  LPMCB M,
  LPMCB N;
  LPMCB Retval = (LPMCB)0L;

  if( !XmsInstalled() )                 /* UMBs are not possible        */
    return Retval,
  XmsControl   XmsControlAddr(), /* get adr to test UMBs        */
  if( (1   AnyUMB(), != 0x81 )  /* UMBs are not possible        */
    return Retval;

  ASM int 0x12,                         /* find top of conventional RAM */
  ASM mov cx,6;
  ASM shl ax,cl,
  ASM mov Mseg,ax;                      /* start the search there       */
  Done = FALSE,

  [redacted]
    { M = (LPMCB)MK_FP( Mseg, 0);
      if( M->type == 'M' )  /* may be an MCB, if any, must be Z */
        { N = M,
          Invalid = FALSE,
          do                            /* determine whether valid MCBs */
            switch(N->type)
              {
              case 'M' :                /* try for next MCB via linkage */
                if( (WORD)(FP_SEG(N)+(N->size)+1) <= (WORD)0xFFFE )
                  N = (LPMCB)MK_FP( FP_SEG(N)+(N->size)+1, 0);
                else                    /* can't be valid, keep looking */
                  Invalid = TRUE,
                break,
              case 'Z'                  /* found end of chain starting at M */
                Retval = M,
                Done   TRUE,
                break,
              default                   /* chain failed test, keep looking  */
                Invalid = TRUE,
              } while( !Done && !Invalid );
        }
      if( !Done )
        { if( Mseg < 0xFFFF )
            Mseg++,
```

```
        else
          Done = TRUE;
      }
    } while( !Done );
  return Retval;                    /* either NULL or first MCB pointer */
}
```

This version of the function works on a brute force basis. It first verifies that UMBs might be present by testing the UMB provider flag for function 0x58. It then gets the initial memory pointer. Moving to the final paragraph of conventional RAM, the function tests each subsequent paragraph aligned byte for the 'M' type signature. Each time it finds such a match, it goes into an inner loop that attempts to verify that this is a valid MCB chain. If the chain reaches a 'Z' type byte without ignoring the original 'M' byte, it has successfully located the first high MCB. If the inner loop fails, the outer loop resumes. If the outer loop runs to completion without locating an MCB chain, the function returns NULL as its value to indicate that no UMBs are present.

It would be possible to avoid the brute force approach and simply use the same chain linking technique that LOADHIGH uses. Unfortunately, that would not work with versions of DOS prior to 5.0 even if UMBs were present, because the linking function did not exist before DOS 5.0. The brute force method allows UMEM to work with older versions and also helps make the following interesting point.

Note that UMB providing XMS managers follow the same rules. Both QEMM and EMM386 use a two-step process that collects free UMB space into regions and collects the regions into a separate chain of MCBs. This causes UMEM to report a smaller total UMB size than it does when run under the XMS managers. The difference is due to function 0x10 creating the region chain and, as a result, making it possible to load programs that control the individual UMBs.

When LOADHIGH is used, MS-DOS bypasses the chain of regions and links the individual UMB segments into a separate chain of MCBs. UMEM then shows the individual UMBs and does not display the region control blocks.

Under DOS 5.0, this is merely an interesting oddity, with DOS 6.0, it's more significant since the LOADHIGH command of DOS 6.0 allows you to specify which region to use for the program being loaded.

We've included a command-line implementation of the UMEM program. Try it both with and without LOADHIGH. You can have DOS 5.0 and DOS 6.0 to see the differences that LOADHIGH makes to its operation.

Allocation Precautions

Each time DOS INT 21h function 4Bh loads a program for execution, it allocates memory for it as well as for COMMAND.COM under requests for available RAM. For an EXE format file, the file's header specifies the amount of RAM needed. If this amount is not explicitly defined at link time, however, the EXE takes all available space.

Most programs terminate when they begin RAM-resident when they are loaded, whether they need it or not. This causes a program to terminate that your programs trim themselves back to no more than they need. Otherwise, you're going to be squatting on other processes' RAM. Failure to do so will result in "out of memory" errors or simply low usable RAM that the system contains.

When a program terminates normally and returns control to its parent process, all RAM allocated to the program becomes available for allocation. If the program terminates through one of the TSR functions, all or part of its memory is released to be used again.

Being a TSR means that it does not give up all available space while they are executing and can turn it back when they leave. Memory allocation for most programs can thus be handled automatically and invisibly by DOS itself. Unfortunately, getting one large block of memory at start up and having it deallocated for you at termination is often inconvenient because it means your program can't spawn

other processes. Modern C compilers usually include in their start-up code the necessary calls to set their RAM usage to just what they require or to 64K, whichever is larger, but at least one popular high-level language, Turbo Pascal, does not do this automatically. Instead, TP gives you a compiler option, "$M", that lets you specify how much memory to use.

Unfortunately, this option uses the DOS value, defaults to "all available space." So an error condition results from attempts to EXEC or SPAWN a child process from TP without using the $M option to make RAM available for the child process. Because of this, the Turbo Pascal exec procedure gained a reputation for being broken. Actually, it was just not adequately documented.

In most high-level language programming, you won't use the direct DOS RAM allocation functions directly, but will use the C library function malloc or one of its relatives, such as calloc or realloc, that are using them indirectly.

The strategy of UNIX is to grab large blocks of RAM by using the DOS functions, then dole it out to the program in much smaller portions as requested. Once RAM is allocated to the program, never (unless I choose) is memory allocated, even after calls to free, until the program returns to DOS. This strategy is the strategy of UNIX, where the allocation of system RAM was a time-consuming process. Under MS-DOS the reverse is true. A number of "improved performance" packages, which replace the standard C library versions of malloc with ones that make calls to the DOS functions, have appeared recently.

On the other hand, each block of memory allocated from DOS requires the addition of a 16-byte MCB, so an DOS allocation is a consequently a paragraph based. So if you want to allocate 4 bytes from DOS, for instance, you have to ask INT 21h function 48h for one paragraph (16 bytes). In order to set up this request, DOS then actually needs two paragraphs: the one you asked for plus one for the MCB. So you lose a paragraph. The point is that the smallest possible direct DOS memory allocation actually uses 32 bytes.

Please don't get the idea from this discussion that malloc is to be avoided. It is required for the DOS functions for the some popular compilers, including Borland's, provide support so that the system is not damaged if you attempt to use the direct DOS interface. The subsequent attempt to use malloc will generate errors. The problem happens because the compiler's library routines depend on unrestricted access to or allocation of RAM. If you grab a block using DOS, the library routines cannot get more and so they report an error.

RAM Allocation Strategies

When a program requests some paragraphs of memory and the memory manager has more than one block free, it's possible to satisfy that request in several different ways. These different ways of allocating memory are known as allocation strategies. DOS provides a function, INT 21h function 58h, to select different strategies.

This function hasn't always been documented. For example, it is described in Microsoft's MS-DOS Encyclopedia but not in IBM's technical reference manual for DOS 3.3. Only with publication of Microsoft MS-DOS Programmer's Reference for DOS 5.0 did the subject come out of the closet.

Since INT 21h function 58h wasn't always documented, we won't spend nearly as much space on it as we did in the first edition of this book, when the allocation strategy capabilities could only be described as sparsely documented. What time and function permitted was to search only from "first fit," "best fit," or "last fit" strategies. With DOS 5.0 six more strategies were added. The original three operate on conventional RAM; three of the new ones duplicate the original ones but search the UMB memory sectors looking into conventional RAM and the fourth new search only the UMB area.

Since the search strategies work on the three original strategies and the six new ones in always the question of which MCB to start to traverse. I describe only the original three here.

First-fit Strategy The first fit strategy is the default action unless you explicitly change things. In the first edition of this book, I wrote that "Even if you do change strategies, DOS will change back to first fit whenever it loads a program, although it follows your selected strategy for all other loading actions." That statement was simply not true for all versions of DOS. In most versions, as a matter of fact, the strategy that you select rules all memory allocations until you change it.

Another major error in my earlier description of the process was the statement that the search for a block would stop as soon as one that was large enough was located. DOS actually maintains, see the Appendix, three segment pointers in the SDA: one for the first block that can satisfy a request, one for the best fit choice, and one for the last block. DOS searches the entire MCB chain or chains, if using the default strategies here, MCB access and reaching the end. Only then does it select which of the three pointers to return as the allocated block.

There's a reason for this seeming waste of effort. While it would be possible to stop short after finding the first block that a strategy would select, doing so would prevent DOS from merging adjacent free blocks back into single larger blocks. Since each such a merge makes an additional 16 bytes of RAM—the MCB for the extra block—available for use, the cumulative effect can be significant. By going through the entire chain for each allocation, DOS makes sure that all free memory blocks are as large as possible.

The first fit strategy causes the operating system manager to make the allocation from the first block that is large enough to satisfy the request. If the block is larger than requested, only enough is taken off the front to fill the request and a new, smaller free block is created for the remainder.

In most cases, the DOS operation means that you'll have only one such block in the system when a program is loaded because the loader often asks for all available RAM, no new block is created. Under these conditions, there would be no difference between first fit and best fit strategies. However, the available RAM has become highly fragmented, and at the same time the block being allocated is small enough to fit in the first free block encountered, the first fit strategy uses that best block.

Best-fit Strategy The best fit strategy requires that the smallest block that will do the job be allocated, regardless of whether it is the first one encountered. As with the first fit strategy, the block is allocated from the front, and any leftover space is put into a new, smaller free block.

This approach guarantees that multiple allocations of small blocks don't fragment RAM unnecessarily. As empty blocks are created at a rapid rate, the best fit strategy tends to use these up quickly, small blocks over and over, leaving the larger blocks free to accommodate requests that require them.

As pointed out in the previous section, in normal operation with only one or two blocks of RAM in use, there's little difference between first fit and best fit. However, you are programming an application that loses its own RAM management and that makes short-term use of large numbers of small blocks of RAM, you'll want to keep this strategy in mind. It could keep you from running out of RAM when you really have enough, if one of the remaining free blocks is large enough to fill your latest request.

I have said this: It's important not to overdiscount it. In fact, as any textbook on operating systems will tell you, first fit is almost always the correct strategy to use.

Last-fit Strategy Unlike either of the other strategies, the last fit technique is designed specifically for allocations that you expect to hang around for a long time, such as TSRs or device drivers.

When a block of RAM is allocated using the last fit strategy, the highest possible block of memory that can satisfy the request is assigned. Normally, this is the highest part of the final block of free RAM. This means that memory allocated at the end of the MCB chain won't ever need to be searched if you switch back to the default first fit strategy for subsequent memory allocations.

In the first edition, I claimed that "The last fit strategy is of limited usefulness," which moved reader Art Rothstein to respond with details of a significant use he had found for this strategy.

We use just it. We load a TSR that provides common services to various applications. Our applications spawn each other perhaps three levels deep. To save RAM we link our applications with the stack in the Microsoft C MSC near heap. When there is insufficient room in the near heap MSC attempts to expand the appropriate segment via INT 21h AH=4Ah. However the code in the TSR is protected by another vendor's ODB and LIB files that are intended to be linked with our applications. We added just enough code to make the TSR look like it provided a reading interface from our applications. One of the functions provided by the TSR allocates memory via INT 21h AH 48h. Suppose application A calls the function and then spawns application B. MSC's spawn uses the near heap to build a copy of the DOS environment to pass to DOS 4BH. If the TSR used first fit for its DOS 48H call, then B's environment would usually be right below application A's data segment preventing A's near heap from expanding to satisfy the spawn call. To avoid this problem we change the allocation strategy to last fit while the TSR has control.

Obviously Microsoft knew what I was doing when it chose to make all three strategies available. Since the details are now documented, I'll end the discussion of memory management here and move on to process management.

Process Management

The idea of a process as a separate executable program that has been loaded into memory—and that may or may not be executing currently—is central to the operation of MS-DOS. The whole basis of TSR programming is that a process may be retained in residence after terminating, but TSRs are not the only processes that DOS manages. Every program loaded for execution, including the command interpreter itself, is a process.

Program Files and Processes

Before we get into the details of how processes are managed, let's first look at how program files are laid out and see how they relate to the eventual executing process.

The COM File Format

The original format for executable files inherited from the CP/M operating system was the .COM file. This kind of executable file starts with all four segment registers containing the same value and executional always starts at offset 0100H, just past the PSP, with the stack pointer set to 0000.

Because the file's total size is limited and advanced techniques cannot be employed, Microsoft has attempted for years to phase this format out—to obsolescence. However, it's still the choice for small, simple utilities and is an excellent choice. It's also useful for other special purposes, as we shall see toward the end of this chapter.

The EXE File Format

The EXE file format is unlike that of the COM file, allowing multiple segments for code, data, and stack. The format also supports relocation and simplifies the linking of several .OBJ files into a single process. A measure of its complexity is that the original EXE format, which is still the standard version used by DOS, provides a foundation for the segmented executable format that is used by Windows and OS/2 programs to support dynamic linking.

While both the .COM and .EXE formats have been officially documented in a number of places, we've found it useful to have specific declarations for both sets of file headers in our UNDOC.DOS.H file. Here is the appropriate excerpt:

```
typedef struct {          /* EXE Program Header                */
  WORD sig,               /* always 0x5A4D, 'MZ'               */
  WORD LeftOver;          /* No. of bytes on last page         */
  WORD Pages;             /* No. of 512 byte pages             */
```

```
WORD Items;             /* No. of RelocationTableItems  */
WORD HdrSiz;            /* in paragraphs                */
WORD ReqSiz,            /* in paragraphs                */
WORD DesSiz,            /* in paragraphs                */
WORD InitSS;            /* in relative paragraphs       */
WORD InitSP;            /* at entry                     */
WORD ChkSum,
WORD InitIP;            /* at entry                     */
WORD InitCS;            /* in paragraphs                */
WORD FirstReloItem,     /* Offset from beginning        */
WORD OlayNbr,
WORD ReservedE 16 ];
ULONG NewExe,           /* offset from front of file    */
} EXE, far * LPEXE,
```

EXE files generated by Microsoft's linkers always use a 512 byte page size for them EXE HdrSiz is always equal to a multiple of 512. Those generated by other linking programs may establish different sizes, so EXE HdrSiz may vary.

When DOS loads an EXE file into memory, it reads the header information into RAM at a temporary location and uses the data stored in the program. The loader then adjusts all addresses in the program as listed in the relocation table, which follows the header, sets the stack segment and pointer from the data in EXE InitSS and EXE InitSP, pushes the values of EXE InitCS and EXE InitIP onto the stack to prepare for control transfer by the program, releases its temporary memory that was separately allocated, and the loader sets DS and ES to the process segment address and enters the program by executing a return instruction. The EXE InitCS and EXE InitIP pushed onto the stack.

If a file is a Windows format, it contains the full header of the original format at its front, and EXE NewExe contains the offset to the additional header within the file. If the file is not in the new format, EXE NewExe is 0.

The PSP: How It Identifies a Process

Earlier when discussing DOS memory management, there was no way to avoid mentioning the Program Segment Prefix. Now we can examine this critical DOS data structure in more detail. The PSP, a 256 byte block located immediately preceding the actual process memory, is the key to process management in MS DOS.

Figure 7-20. The PSP and Its Relation to the Process

The PSP contains the DOS state, file handles, etc., for its process. The segment address of the PSP itself provides a unique value in the single-tasking environment for which DOS was designed (see Chapter 6 for a discussion of more complex PSPs under Windows Enhanced mode, identified by which the process can be located and managed). Thus the PSP segment address is also known as the Process Identifier or PID value.

History, Purpose, and Use The Program Segment Prefix came to MS-DOS as a way of Seattle Computer Products' 86-DOS which, for compatibility, took the idea from Digital Research's 8080 CP/M operating system. As MS-DOS has progressed through the years, however, the PSP evolved into far more than its CP/M equivalent. The PSP now embodies many of the ideas provided by other operating systems such as UNIX and Multics, by the stack frame of the process descriptor. By proper use of information kept in the PSP, a process can pass data to other processes that it spawns or can return information back to its parent process. At the same time, many fields of the PSP are vestigial holdovers from the days of CP/M.

The primary purpose of the PSP is to contain the system information necessary to start, run, and finish a specific process. This information includes, but is not limited to, the address of the routine to which control should be passed when the process terminates, a list of handles by which the process identifies its files, and the address of the environment space belonging to the process, the identity of the process' parent process, and (at least for COMMAND.COM) arguments passed directly to the process when it was invoked.

A second purpose is to provide methods of accessing DOS functions without INT 21h; this was much more important in earlier times than it is today. With CP/M the interface to 8-/16-bit Basic Disk Operating Systems, the lowest level of the INT 21h functions, was by way of a far-memory call to location 0005h. Compatibility was provided by placing 0005h in the PSP of every process and by providing a jump to the dispatcher area of MS-DOS itself, which has grown in complexity and functionality since Version 2.0 but is still unconnected with Version 6.0. It goes to a location that has been moved to the right place.

Many UNIX systems provide system-specific routines enough to call on the user's stack frame, as do with the transition to UNIX-like capabilities in MS-DOS 2.0's special treatment of INT 21h was added to the PSP at offset 0050h. At one time this was identified in Tandy's MS-DOS 2.1 *Technical Reference* as "for UNIX compatibility."

Neither of these purposes is widely used. Most programs today simply use INT 21h or, if the program is coded in a high-level language, its equivalent.

(Usually) Unique Process Identifier MS-DOS actually has only a critical process because it uses the associated PSP as a convenient pool area to be marked as for memory-control purposes. Yet MS-DOS can be used for multitasking between multiple processes. Like most multitasking, real-mode operating system without memory protection, it passes control from process to process by changing the "current process" ID.

Throughout the MS-DOS documentation, you'll find references to a "current process ID," "the process identification number," "current process ID number," "PID," "PID," or "PID." All of these identifiers refer to the segment address of the PSP associated with the process that is currently active. However, the documentation rarely explains precisely what the PID is.

The process identifier is nothing more than the segment address of the PSP associated with that process. Without memory-access restrictions, which the design of MS-DOS was based on, the value of the PSP segment address is unique. Only one PSP can be located at any specific segment address, so the PID identifies only a process with no possible ambiguity.

Unfortunately, when the system moved its multitasking capabilities under Windows Enhanced mode, the concept of the PID vanished. To deal with this situation, the Windows SYSTEM.INI file has a two-section entry, the [386Enh] section. UniqueDOSPSP= and PSPIncrement= . As with the

Beginning with DOS 3 DOS uses the virtual machine ID to differentiate processes. Thus, the combination of VM ID and PSP is a unique identifier.

Starting with version 5 DOS provided two undocumented functions and one documented one to store and retrieve the PSP segment of the current process, thus activating one or another set of data stored in the kernel. (SDA and DOS 3+ Internals documented because others with version 5. The current process is set using INT 21h Function 50h. The current process can be queried either with INT 21h Function 51h or in DOS 3+ and higher with the equivalent Function 62h.

It is important to note and understand that none of the PSP functions actually deals with the PSP of the program that calls them. As we saw in Chapter 6, all that they really do is move a 16-bit value either to or from the location in the SDA swappable Data Area maintained by DOS. If the value in that area is corrupted, the Get/Set PSP functions return the incorrect value with no indication of error.

Here appears to be a great deal of confusion on this point. For example, even Duncan's *Advanced MS-DOS Programming* states that Function 62h "allows a program to subsequently recover the PSP address ... even if the program has terminated without using the standard program exit."

In fact, the Get PSP function always returns the value that was last established in the SDA via Set PSP, whether or not that corresponds to the current process in DOS. Not necessarily to the PSP of the call that invoked Get PSP, to the current process in DOS, not necessarily to the PSP of the call that invoked Get PSP, or to the process that has been activated by an interrupt. Get PSP returns the PSP of the foreground process or of the ISR's PSP. That's what makes the Get/Set PSP functions important. They provide the mechanism for switching between multiple tasks in MS-DOS. It's often said that DOS is single-tasking, but this phrase merely means that only one process owns DOS at any given time.

Whenever the current process is switched, whether by your own multitasking code or by a TSR, you must also make sure that the current PSP also be switched if any I/O activity is to occur. Otherwise, the files will be owned by the original foreground process, rather than your own files will be affected.

The three get/set PSP functions are described in further detail in Chapter 9 on TSRs and DOS multitasking.

Undocumented Areas of the PSP Less than one-third of the 256-byte area of the PSP has been documented. Table 6.1 in Section 6.2 supplies information about the remaining parts. Not all of them, however, have ever been put to use.

The following program, PSP.H, is taken from our UNDOC.DOS II header file, which provides typedefs for all the DOS structures described in this chapter. For information on PSP fields owned by Windows and by Novell NetWare, see Chapters 3 and 4.

Figure 7-21 PSP Details

```
#define ENV_FM_PSP(psp_seg) (*((WORD far *) MK_FP(psp_seg, 0x2c)))
#define PARENT_psp_seg)     (*( WORD far *) MK_FP(psp_seg, 0x16)))
typedef struct {            /* Program Segment Prefix          */
  WORD sig;                 /* 0000 always CD 20 (INT 20)      */
  WORD Nxtgraf;             /* 0002 first unused segment       */
  BYTE Skip1;               /* 0004 filler to align next       */
  BYTE cpmCall[5],          * 0005 CP/M-like service call     */
  FP   ISV22;               /* 000A documented ISR vectors     */
  FP   ISV23;               /* 000E " (saved at start)         */
  FP   ISV24,               /* 0012 "                          */
  WORD Parent_ID,           /* 0016 PSP of parent process      */
  BYTE HTable[20];          /* 0018 indices into SFT           */
  WORD EnvSeg,              /* 002C environment segment        */
  FP   SavStk;              /* 002E saved SS:SP at INT21       */
  WORD Nhdls;               /* 0032 nbr of handles avail       */
  FP   HTblPtr;             /* 0034 ptr to handle table        */
  FP   ShareChn,            /* 0038 SHARE's closing chain      */
  BYTE Skip2,               /* 003C unknown                    */
```

```
BYTE TruNamFlg,         /* 003D APPEND's TrueName flag  */
BYTE Skip3a[2];         /* 003E Used by Windows?        */
WORD Version,           /* 0040 Major, minor vers level */
BYTE Skip3b[6];         /* 0042 Used by Windows?        */
BYTE WOldApp;           /* 0048 Windows OldApp Flag     */
BYTE Skip4[7],          /* 0049 unknown                 */
BYTE DispP[3],          /* 0050 Unix-like dispatcher    */
BYTE Skip5[2],          /* 0053 unknown                 */
BYTE ExtFCB[7],         /* 0055 extended FCB1 area      */
BYTE FCB1[16],          /* 005C documented FCB areas    */
BYTE FCB2[20],          /* 006C                         */
BYTE Tails,             /* 0080 "command tail" count    */
BYTE Tail[127],         /* 0081 start actual data here  */
} PSP, far * LPPSP,
```

The ENV_SEG PSP(psp_seg) and PARENT(psp_seg) macros make it simple to obtain segment addresses for the associated environment block and for the process' parent process. When using either a Borland or Microsoft C compiler, you can get the segment address of your program's PSP from the global variable _psp.

If you elect to declare pointers to your PSP by using MK_FP(psp,0), you can then access all of the PSP elements as structure members. For instance, if you declare the pointer as PSPptr, the environment's segment address could be obtained as PSPptr->EnvSeg, and the parent process segment would be PSPptr->Parent_ID.

DOS Termination Address

Although the five interrupt service vectors stored in the PSP are located there for compatibility with CP/M, one of the more valuable ways to hook into a process at termination time is provided with access to the process's terminate address, by providing DOS Exit function capability. The address is stored at INT 22h (the INT 22h vector). Executing this address is the termination address. What is not clearly stated is the fact that the address stored at INT 22h in the PSP is the interrupt service routine that is executed when the process terminates.

To hook this vector and cause your own code to be executed when the process terminates and before control is returned to the calling program, just use the routines shown in Figure 7-22, with your own code inserted as noted. Execute SetHook with ES pointing to the PSP. DoHook will be called automatically at termination time.

Figure 7-22. Process Termination Hook

```
SetHook PROC
        MOV     AX,[ES:000Ah]           ; save old offset
        MOV     word ptr CS:OldVec,AX
        MOV     AX,[ES:000Ch]           ; save old segment
        MOV     word ptr CS:OldVec+2,AX
        MOV     AX,offset DoHook
        MOV     [ES:000Ah],AX           ; set in new vector
        MOV     AX,CS
        MOV     [ES:000Ch],AX
SetHook ENDP
OldVec  DD      0                       ; place for old vector

DoHook  PROC    FAR
; whatever you need to do is coded here
        JMP     [CS:OldVec]             ; then chain to original
DoHook  ENDP
```

The termination address stored at INT 22h in the PSP is not the return address to the Exec function call. INT 21h function 4B00h that the parent used to invoke this process. Obviously, then,

when DOS transfers control to this address it is ready to return to the parent. DosHook is grabbing control instead so when DosHook is executed all memory allocated to the terminating process has already been released, including the memory containing the DosHook code. All files have been closed and the current PSP has been set to that of the parent. In DOS 3.0 and later, the registers have been restored to the values they had when the parent performed the EXEC.

Basically, all DosHook should do is uninstall any special handlers that the program had installed so that the system is not left pointing to addresses that are no longer valid. No other actions should be attempted, and by all means no file access or other I/O should be tried since the context could easily be dependent on the parent program. For more complex exit processing, you are better off using routines set up with atexit() in C. Note though that the C routines are called only for normal process termination and are not executed in case of fatal errors or other abnormal conditions.

For another approach to exit handling, see the discussion of INT 21h AX=1122h, Process Termination Hook, in Chapter 8.

Other PSP Fields

The first full undocumented area of the PSP is the word at offset 0016h, which contains the PID of this process' parent process. If this process is the current command interpreter, its own PID appears here, even if it is only a suspended shell that can be terminated by the EXIT command. We can use this to trace through these pointers from one PSP to the parent PSP and thus locate the master command interpreter. However, all we can do by tracing this is to locate the current shell which may not be the master. As noted earlier, INT 2Eh can be used to find the master copy of COMMAND.COM; more details appear in Chapter 10 on command interpreters.

Immediately following the PARENT pointer at offset 0018h is the 20 byte handle table. If a file handle value in this table represents an index into the System File Tables maintained by DOS. The first five of these are normally reserved for the standard handles for stdin, stdout, stderr, stdaux, and stdprn. Note that the first three handles refer to the same System File Table; see Chapter 8 on the DOS device-driver entry for device CON. Unused handles have the value 0FFh.

The next undocumented area is the double word at offset 0022h, which the DOS dispatch code uses to save SS:SP when this process enters INT 21h; see step 6 in Figure 6-7. Saving the stack location in the PSP rather than in DOS own data area makes multitasking possible by permitting DOS to switch to other processes without losing each process where it was last halted. (That is treating DOS processes as reentrant.) However, MS-DOS itself has not yet taken advantage of this capability.

Right behind is PARENT_ENV, which is only supported in version 3.x, which permits you to redirect the handle table and thus make more than 20 file handles available to your process. A discussion of DOS function INT 21h AH=67h, which is the recommended way to manipulate this area. An alternative to function 67h appears in FHANDLE.C, in Chapter 8.

The next two bytes of this region are the word NHDLS at offset 0032h, which defines the number of handles in the table. If this process attempts to open another file or device when this many handles are already in use, it appears DOS error. The following four bytes, HDLPTR at offset 0034h, are a DD pointer to the location of the handle table. By default, NHDLS is set to 20, and HDLPTR is PSP:0018h, thus describing the handle table in the PSP.

The double word at offset 0038h was set to 0FFFF:FFFFh in DOS versions prior to 3.3. Later DOS versions set this to point to a previous PSP when SHARE is used, creating a chain of PSPs used by SHARE's record-locking code. (Only one PSP is expected by a given machine.)

AH=EXEC sets the byte at offset 3Dh of the PSP to maintain its undocumented flag for INT 24h functions 59h, 5Dh, and 65h. At version 5.0, DOS began storing the major and minor version values at offset 40h. SETVER uses this to "lie" to applications about the DOS version number. WINOLDAP in Windows uses the byte at offset 48h setting the bottom bit when running old (that is, DOS) applications. Finally, offset 50h is the start of an extended FCB field.

Spawning Child Processes

As is discussed in Chapter 10, every program run under MS-DOS can be thought of as a child process. Even the first one loaded as part of the boot action (that is, the loader that is read in from the boot sector by the disk's ROM Bootstrap routine).

A child process is simply a process spawned by some other process, what is called the parent. Again, except for the bootstrap and/or code that initially brings your system into action, every process in the system is a child of some other process.

The boot-up procedure spawns one child, the command interpreter specified by the SHELL line in CONFIG.SYS or COMMAND.COM by default if no SHELL is specified. This process is what most users perceive to be DOS itself. Each time a program's name is typed on the command line, that program is spawned as a child of the command interpreter for execution.

If the spawned program is itself a menu or other type of shell routine, it may in turn spawn children of its own, which then execute and return control to their parent. Should control ever return to the bootstrap loader, the result is the error message "Bad or missing command interpreter" and a locked system requiring rebooting. However, DOS will also prompt for the full pathname to the command interpreter if it is unable to locate the specified one while performing the initial program load or bootstrap process.

Locating Parent Processes

From time to time, a process needs to be able to trace its ancestry. It is not always possible. For example, which program or task is COMMAND.COM is always its own parent. (For excellent reasons, see Chapter 10 and/or the Tom Swan opus elsewhere.) However, if the process is running as a child of another program, such as a command interpreter such as COMMAND.COM, the job of locating its ancestors is straightforward. Here's how it is accomplished.

Locating Ancestors The only key item to build is the PSP; the PARENT word described previously makes it possible for a program to trace its ancestry. (Let's point out the closest command interpreter shell, which, by definition, is the one process that is its own parent.)

Thus a program that needs to trace its ancestry can easily locate its own PSP value (get the program process ID), locate the process's PSP, check the process control block to find the PARENT word, which points to the PSP that contains the DOS PSP of the next command interpreter program encountered in the trace.

Use of this Capability A sample program in C that uses this capability to trace its ancestry appears in Figure 7-23.

Figure 7-23 Tracing Process Ancestry

```
/*
 * ROOTS.C (with apologies to Alex Haley)
 * Trace Your Ancestry!
 * Jim Kyle, 1990
 * revised August, 1992, jk to include UNDOCDOS.H
 */
#include <stdio.h>
#include <stdlib.h>                 /* required to get _psp for MS  */
#include "undocdos.h"

WORD parent, self;

main ( void )
{ self = _psp;                      /* start with own PSP value     */
  parent = PARENT( self );
  do
    { printf( "PID    0x%X, PARENT = 0x%X\n", self, parent );
```

```
        self = parent;
    }
  while (( parent = PARENT( self ) ) != self );
  return 0;
}
```

The program simply copies its own PID into the variable "self" and then uses it and the defined macro PARENT to retrieve the parent's PID in "parent."

It enters the program loop, reporting the values of the variables "self" and "parent" at each level and then redefining them both until the program reaches the level at which the two values match. This is the command interpreter. At this point the program returns. It's most instructive, by the way, to run this program from some environment rather than from the command line because that generates at least one level of ancestry before the command interpreter is reached. For example, we can run ROOTS inside of DEBUG inside another copy of DEBUG:

```
D:\UDOS2\CHAP7>debug \dos\debug.exe roots.exe
-g
-g
PID = 6C7E, PARENT = 672E
PID = 672E, PARENT = 6150
PID = 6150, PARENT = 6139
```

Here 6C7E is ROOTS, 672E and 6150 are DEBUG, and 6139 is the current command interpreter since we're running a secondary shell invoked from my text editor. Naturally, we could use the code we developed earlier in UDMEM.C specifically the function programmatic interface to find the ASCIIZ names of these ancestors.

Device Management

In addition to memory, the operating system must manage all devices connected to the CPU, such as the disk drives, the keyboard, and any displays. DOS manages and issues requests to device drivers, which then talk to lower-level interfaces such as the ROM BIOS (Basic Input Output System) or a device controller.

Why Device Drivers Exist

Older operating systems and even MS DOS 1.x included all hardware dependent code necessary to deal with input and output as an integral part of the system itself. This made it necessary to bring out version 1.1 of MS DOS when IBM made available the 360K double-sided floppy disk drive and made it impossible to use any kind of hard disk concurrently on a DOS 1.x system. Improvements were obviously in order.

A major part of the upgrade provided by MS DOS 2.0 was the installable device driver capability. The idea, which originated at MIT with the MULTICS mainframe system, found its way into DOS as well as into Bell Labs' UNIX, but the idea was significantly improved on its way into DOS. The designers concentrated all hardware dependencies into small modules that were separate from the main mass of operating system code, but that still required the user to rebuild and relink the operating system in order to change any drivers. This was true for both MULTICS and UNIX. In DOS, on the other hand, all you do to change a driver is modify CONFIG.SYS and reboot. As we show below, by the end of this chapter even that process can be made simpler, and a new driver can be installed from the command line with absolutely no change to the main operating system code itself.

An installable device driver is a code package that forms a self-contained unit capable of initializing itself and through which all communication to and from a specific hardware device can be channeled. The format of the driver and its command interface is specified by the MS DOS documentation.

Devices, so far as DOS is concerned, come in two flavors known as character and block. Character devices are those that can deal with a single character at a time, such as the CRT, the keyboard, the printer, or the serial port. Block devices are those that, like disk drives, must transmit data a block of data at a time, at least at once. Drivers for the two types are distinguished by a single bit in the device header attribute word, a bit that governs the fact that some of the command functions make sense for only one of the types. Otherwise, identical structures and request identical interfacing techniques.

By separating hardware dependencies into these modules, only new drivers, rather than a complete operating system upgrade, need to be developed when a new hardware device becomes available, the new device can be switched to become usable with any older system that can accept the driver.

Hardware-Dependent Details

In general, those special actions tend to be highly device specific and vary from one device to the next. These are the actions required to initialize the device and prepare it for use, those required to send data to it, and those required to receive data from it.

You might recall that some devices need only two of these groups, but not both. For example, the keyboard never receives data from a printer. However, the keyboard does have to receive certain commands from the operating system to acknowledge that its output has been accepted and sometimes it needs to send status conditions from the printer. These peripherals are I/O devices, not just Input or Output devices.

Other details are associated with specific hardware items rather than with general logical functions, including the addresses through which communication is achieved, the handshake protocol used to transfer data to and from the device, and the actual port-level instructions and status.

All of this hardware dependent detail is concentrated within the single driver that services each device. In order for DOS to use them, they are grouped into a small collection of logical functions as specified in the DOS documentation.

Logically Required Functions

The DOS documentation specifies 17 logical functions, all of which must be recognized by each expanded device driver, regardless of whether that function makes sense for that device. For example, the meaningless act of media check for a CRT device must provide adequate response to be performed only with DOS permission, as you'll see later.

Normal input-output operations are implemented with a simple read or write request to a device number as the device table of device addresses translates that number to the device address. If the specific function does not apply to this driver, the command is treated just like an inappropriate status code with no other action performed.

Congruence of Files and Devices

One of the most useful results of the device driver idea is that MS-DOS treats files and devices in exactly the same way. However, it's not exactly obvious why you might want them to be so. At first glance, files and devices don't seem to have much to do with each other.

But it's the stream of data that's interesting. For both files and devices, what really counts is the stream of data. Your program doesn't need or even know whether such a stream comes from a file, from the keyboard, or from communications port. Then there'll be that much simpler a deal to work when some new type of input device arrives on the scene.

This device-file independence is a major advantage when compared to older systems that require totally different programming to achieve data from the keyboard than is required to achieve otherwise identical data from a file.

Unfortunately, most of the keyboard's capability as an input device can be used through the drivers, nor can anywhere near its top speed be obtained from the CRT. If your program must read

true video image display system with hotkey control you'll be forced to go directly to the video display controller with your output and to use BIOS routines to read the keyboard without waiting until the operator presses ENTER.

Universal programs that run under MS DOS are able to take full advantage of the power offered by device drivers. This is not a limitation inherent in the idea itself, but rather an artificial one imposed by the design of MS DOS and its failure to anticipate all future needs. Or maybe it's limitations inherent in the idea of device independence. Windows device drivers deal with this problem by resorting to the use of separate specifications for display drivers, keyboard drivers, and so on.

One interesting by-product of the rules devices enforce is that all your named devices can be accessed as files in any disk directory. This comes about because the DOS routines that open both devices and files always search for devices first. If a device name is the same as the name of the file you are trying to open, the device will be opened instead. Because most of the procedures that determine whether a given file exists depend on trying to open the file and then detecting the error if it cannot be opened, most routines show that any device exists as a file in any directory you happen to test. Nevertheless, a device does not show in the directory listing.

This can be used to test for the existence of a directory itself. Because if you try to open a device by attempting to find it in a nonexistent directory, the directory error occurs before the device access attempt. That error in turn indicates that the directory itself cannot be accessed. If the directory can be accessed, the device can also always be accessed. The following batch file uses this aspect of DOS devices:

```
@echo off
rem isdir.bat
if exist %1\nul goto exists
echo No such directory
goto done
:exists
echo Directory exists
:done
```

```
C:\UNDOCRY>type isdir.bat
@echo off
rem isdir.bat
if exist %1\nul goto exists
echo No such directory
goto done
:exists
echo Directory exists
:done

C:\UNDOCRY>isdir \foober
No such directory

C:\UNDOCRY\KYLE>isdir \undocry\kyle
Directory exists
```

Tracing the Driver Chain

In order to operate at all, MS DOS must provide at least a minimal set of built-in device drivers. Yet to achieve the real advantages of expansion, it's necessary to be able to insert new drivers at will and to have the power of replacing an existing driver with a new version.

In order to achieve these goals, DOS organizes the drivers as a single linked chain, with a defined starting point that is always at the same place within any specific DOS version. The location differs from one version to the next, however. Each driver in the chain includes as part of its structure a pointer to the next one, and the end of the chain is signaled by the value FFFFh in the offset portion of the next-driver pointer. Understanding this linked list (Figure 7-24) shows how the chain of device drivers is organized in DOS.

The original device chain is patched in by a hidden system file, IO.SYS in PC DOS, IBMBIO.COM in MS DOS. If you add drivers to your system using the DEVICE= command in the CONFIG.SYS file, they are patched into the chain by the initialization portion of IO.SYS each time you boot your system.

Subsequent sections of this chapter describe the detailed organization of the device driver chain, tell how drivers are initialized during system boot-up, and then show you how to locate the start of the chain for any version of DOS and how to trace the driver chain and find out what is in your system.

Figure 7-24. The Device Driver Chain in DOS

Organization of the Device Driver Chain The device driver chain is a single linked list structure with a defined starting point. The link itself is a far pointer—32 bit segment offset format—that forms the first four bytes of each device driver. The starting point is the driver for the NUL device.

The NUL device's character input is the bit bucket for both input and output. Any output sent to NUL simply vanishes without trace, and any attempt to read input from this device encounters a permanent EOF condition. To install a device with these characteristics is trivial. NUL also serves as the anchor location for the driver chain.

As delivered, NUL's link pointer holds the address of the supplied CON driver—the default console or keyboard/CRT device. This driver is located near the front of the IO.SYS data area, which normally starts at a segment address 00:0070. The NUL driver, however, is located near the front of the DOS data segment (DSEG) within the SysVars structure, which is at a much higher address.

Because the DOS handle processing routines know where the NUL driver is located, they can trace through the chain to locate any required driver.

As already mentioned, the DOS routines always go through the device chain looking for a match between the name of each character device and the requested file name whenever an attempt is made to open a file for input or output. Only when no match is found in the driver chain does DOS search the directory for a named file. This makes it impossible to either create or access a file that has the same name as a device. It might be possible to develop a form of security system based on this fact—first create a file, then install a device with the same name and providing a secure method for changing back to the file's name during operation.

Note that character devices have names that are used in the search; block devices are referred to as A:, B:, and so on, instead of by name. During a name search, block drivers are simply skipped. Because one must refer to a name to find the search an existing driver is replaced simply by inserting the replacement driver into the chain where it will be encountered first and being sure that it has the same name.

How Drivers Are Initialized When you add new drivers using CONFIG.SYS, each driver is added to the front of the chain as it is encountered. DOS copies the link values from NUL into the new driver's link and then puts the new driver's address into the NUL link instead.

[illegible] character device drivers are added into the chain in the same way. The search always begins at the NUL driver, guaranteeing that any new drivers added will be found before the built-in ones.

Completing the patching that inserts each driver into the chain is not done though until the last step in the device initialization. First, the initialization routine calls the driver's own internal initialization code. If the driver encounters any problems, it is skipped with an advisory message. If the initialization completes without error, DOS checks the device attribute word to determine whether the driver is for a character device or a block device. If it is for a character device, it is added to the chain immediately.

However, for a block device, DOS checks the number of units installed by the initialization routine. A zero value signals DOS not to install the driver even though no errors were detected. Otherwise, DOS uses the value returned in the next drive letter in sequence, then creates a DOS Drive Parameter Block (see the Appendix for the device call IOCtl to the DPB, or from an interrupt 21h function that returns a pointer to the DPB). Next, DOS builds a Current Directory Structure (see the Appendix for the device call IOCtl) for the drive, which it links the DPB back to the device driver. Only after all these steps are successfully completed does DOS patch the driver into the chain.

If you have a special device on your personal system, you can easily change the name and specify that it be treated like a character device (DEVICE=) line. However, when you do this you must be aware of several caveats. The first section pertains only to block devices. The code that processes CONFIG.SYS device= statements for the Disk DPB for each such device named and fills in the number of units value. Also, the drive is passed to DOS by the driver when it initializes itself. DOS uses this to set the default drive. Thus, if you have more than one block device in the system, the code should return different break addresses and these values should not be changed. Any code that will be needed after DOS calls the driver's initialization function.

Character devices and block devices share the same list, which is not patched by the SPEED.SYS program. However, for their order, you must be sure that the character drivers appear in the file before any of the block drivers for the same reason.

Finally, a word of caution. To utilize a character device, you must open it. This avoiding those possible problems. Note that opening a device is necessary only to write to it. Otherwise, it is not necessary to open it. When that's the case, be very careful and [illegible] unnecessary opens or crashes. Double-check to be sure that any new break address pointer is not wiping out driver code.

Locating the Start of the Chain The start of the device driver chain, like that of the MCB chain, is not documented. However, it can be determined using the undocumented INT 21h function 52h, which returns the List of Lists. The NUL device driver header, the actual header, not a pointer, that forms the beginning of the chain, is located in the List of Lists.

In DOS 2.x, the NUL header begins 11 bytes past the address returned in ES:BX by INT 21h function 52h. With DOS 3.0, the offset is 28h, but in 3.1 that came down to 22h and there it has remained.

The following code fragment shows how to obtain ES:BX with the address of the NUL driver for DOS 3.1 and up, for earlier versions. Later, change the 22h to the appropriate value.

```
mov     ah, 52h   ; get List of Lists
int     21h
add     bx, 22h   ; NUL driver offset, DOS 3.1+
```

Tracing It Through Once you have located the start of the device driver chain, actual tracing through the devices is a relatively simple application of DOS function 0. The only complicating factor is the need to distinguish between character and block devices and to report block devices differently because they have no names.

The sample program shown in Figure 7-25, written for MASM version 5.1 but usable with other assemblers that support the simplified segmentation directives, shows how simple it is

Figure 7-25 Tracing the Device Chain

```
; DEV.ASM--for DOS 3.1+
.model small
.stack

.data
blkdev  db      'Block: '               ; block driver message
blkcnt  db      '0 unit(s)$'

.code
dev     proc

        mov     ah,52h                  ; get List of Lists
        int     21h
        mov     ax,es                   ; segment to AX
        add     bx,22h                  ; driver offset, 3.1 and up
        mov     di,seg blkdev
        mov     dx,offset blkdev

dev1:   mov     ds,ax
        lea     si, [bx+10]             ; step to name/units field
        test    byte ptr [bx+5], 80h    ; check driver type
        jz      dev3                    ; is BLOCK driver

        mov     cx,8                    ; is CHAR driver
dev2:   lodsb                           ; so output its name
IFDEF INT29
        int     29h                     ; gratuitous use of undoc DOS
ELSE
        push    dx
        mov     dl, al
        mov     ah, 2                   ; Character Output
        int     21h
        pop     dx
ENDIF
        loop    dev2
        jmp     short   dev4            ; then go look for next one

dev3:   lodsb                           ; get number of units
        add     al,'0'                  ; assumes less than 10 units!
        push    ds
        mov     ds,di
        mov     blkcnt,al               ; set into message
        mov     ah,9
        int     21h
        pop     ds

IFDEF INT29
dev4:   mov     al,13                   ; send CR and LF to CRT
        int     29h                     ; gratuitous use of undoc DOS
        mov     al,10
        int     29h
ELSE
dev4:   push    dx
        mov     ah,2                    ; Character Output
        mov     dl,13                   ; send CR and LF to CRT
        int     21h
        mov     dl,10
        int     21h
        pop     dx
```

```
ENDIF
        mov     si,bx                   ; back up to front of driver
        lodsw                           ; get offset of next one
        xchg    ax,bx
        lodsw                           ; and then its segment
        cmp     bx,0FFFFh               ; was this end of chain?
        jne     dev1                    ; no, loop back
        mov     ax,4C00H                ; yes, return to DOS
        int     21h
dev     endp
        end     dev
```

When DEV.EXE is run on a MS-DOS 6.0 system, it produces the following list of drivers. The bottom 15 are those contained in the hidden file IO.SYS; the 3-unit block driver controls drives A, B, and C, and the other 10 are the standard DOS devices. The less than 26 reports result from the fact that some of the new Microsoft drivers allow 32 units, while DEV assumes that no more than 26 are present. The duplication of block drivers is an artifact of having SMARTDRV.EXE installed; the system had only four disk drives.

```
NUL
Block: 4 unit(s)
Block: 3 unit(s)
DBLSPACE$
CON
$HMAXXXX0
XMSXXXX0
Block: 4 unit(s)
CON
AUX
PRN
CLOCK$
Block: 3 unit(s)
COM1
LPT1
LPT2
LPT3
COM2
COM3
COM4
EMMXXXX0
```

The duplicate CON is DV_ANSI.SYS because it appears in the chain ahead of the standard CON driver, it is always used.

It is worth noting that if assembled with a -DINT29 flag, DEV.ASM makes gratuitous use of undocumented DOS. INT 29h is the *fast put char* interrupt called from DOS when sending characters to a device whose attribute word has bit four set. It is tempting to use INT 29h here because it does simplify the code just below label dev2. However, Chapter 1 notes that there really are places you should use documented DOS instead of undocumented DOS, even when it seems like more trouble. Character output in this program is one of those places. Although this program absolutely demands use of undocumented INT 21h Function 52h, there are several reasons why it should not use undocumented INT 29h:

- Essentially the same functionality is available with INT 21h Function 2, although it may be a little slower.
- INT 29h output is not redirectable. Because this program displays block devices using INT 21h Function 2, which is redirectable, using INT 29h elsewhere means that running DEV > TMP.TMP ends up displaying character devices on the screen and block devices in the file. Pretty silly!

Thus DEV provides a nice demonstration of when undocumented DOS is needed and when it definitely isn't. Exercise some discretion here. Don't use undocumented DOS if you don't need to. End of lecture.

Loading Device Drivers from the DOS Command Line

To complete what we've learned about DOS resource management, let's create a program you can use to load device drivers from the DOS command line, without having to edit CONFIG.SYS and reboot.

Ever since an MS-DOS program that required the presence of a device driver, and you wished you had a way to install the driver from the command line prompt rather than having to edit your CONFIG.SYS file and reboot the system? Of course, you can be thankful that it's so much easier to reboot MS-DOS now than it was to rebuild the kernel, which is what you had to do to add a device driver to a XENIX. While DOS 5 borrowed the idea of installable device drivers from UNIX, it often forgotten that DOS 5 did not approve of the installation of device drivers by repeating the loading of a device driver multiple times in the CONFIG.SYS.

Still, most of the occasionally wish we could just type a command line to load a device driver and be done with it. Or to unload installable device drivers. Also developers of device drivers often wish they had a way to debug the initialization phase of a device driver. This type of debugging usually requires a debugger device driver that loads before your device driver, and requires elaborate real-mode emulation to work with loadable device drivers after the normal CONFIG.SYS stage.

Well, we can't do much about the inability of MS-DOS device drivers to not stay resident, it's relatively simple to write a program that will load a device driver from the command line. We present such a program, DEVLOD, written in a combination of C and assembly language. The program that follows is not the same as the one that appeared in the first edition of this book, nor the slightly modified version that appeared in the November 1991 issue of *PC Tech Journal*. This version is more extensively debugged, and now includes code that corrects several problems that made the original unsuitable for loading block devices under DOS 4.0 or 5.0. This version also reliably determines the correct drive letter to use when adding new block devices.

Many readers have provided feedback that helped improve DEVLOD over its existence. Some of the most valuable feedback has come from Jeff Wright, who found a number of problems in earlier versions and suggested solutions for most of them, which I gratefully acknowledge here. Another who spotted many of the same problems, and provided a version that was Geoff Chappell. Thanks to Geoff, the new version is free of the dependencies on the specific version of DOS itself. It does rather rely on using the undocumented, but well-known, internal status structure. Others whose comments helped greatly were Nick Petrella, Jim Wooster, William T. Wonnacott, and Jay Lowe, whose testing helped uncover a number of subtle and related problems. Most of the details of the reported problems, in addition to significant improvements, were provided by Geoff. I've retained DEVLOD's use of the UNDOCUMENTED DOS function, so that you wouldn't have to worry about being confused by the various offset values sprinkled throughout the original.

To use the program, the first argument to devlod must be DEVLOD, followed by the name of the device to be loaded, and any parameters that you would supply them in CONFIG.SYS. For example, instead of placing the following in CONFIG.SYS:

```
device=c:\dos\ansi.sys
```

you would type the following on the DOS command line:

```
C:\>devlod c:\dos\ansi.sys
```

There are several ways to verify that this worked. First, you can write ANSI strings to CON and see if they are properly interpreted as ANSI commands. For example, after a DEVLOD ANSI.SYS the following DOS command should produce a DOS prompt in reverse video:

```
C:\>prompt $e[7m$p$g$e[0m
```

For maximum accuracy, you can tell that the new driver has been installed by running DEV and inspecting its display of the device chain. You can see your new driver at the top of the list, right after NUL and ahead of any identically named drivers loaded earlier:

```
C:\UNDOC\KYLE>dev
NUL
QEMM386$
  .
C:\UNDOC\KYLE>devlod \dos\clock.sys
C:\UNDOC\KYLE>dev
NUL
CLOCK$
QEMM386$
  ..
```

DEVLOD loads both character device drivers (such as ANSI.SYS) and block device drivers (drivers that support one or more drive units such as VDISK.SYS), whether located in .SYS or .EXE files.

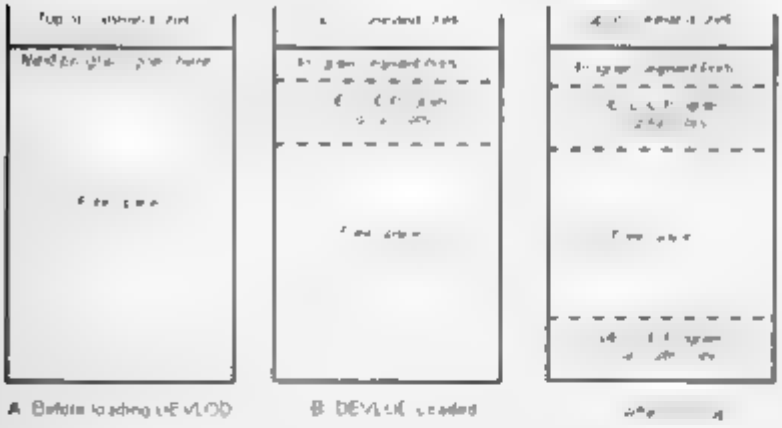
How DEVLOD Works

Here's the basic structure of the DEVLOD program:

```
startup code (C0.ASM)
main (DEVLOD.C)
    Move_Loader
        movup (MOVUP.ASM)
    Load_Drvr
        INT 21h Function 4B03h (Load Overlay)
    Get_List
        INT 21h Function 52h (Get List of Lists)
        based on DOS version number
            get number of block devices
            get value of LASTDRIVE
            get Current Directory Structure (CDS) base
            get pointer to NUL device
    Init_Drvr
        call DD init routine
            build command packet
            call Strategy
            call Interrupt
    Get_Out
        if block device
            Put_Blk_Dev
                for each unit
                    Next_Drive
                        get next available drive letter
                    find last existing DPB
                    INT 21h Function 53h (Translate BPB -> DPB)
                    poke CDS
                    link into DPB chain
        Fix_DOS_Chain
            link into dev chain
        release environment space
        INT 21h Function 31h (TSR)
```

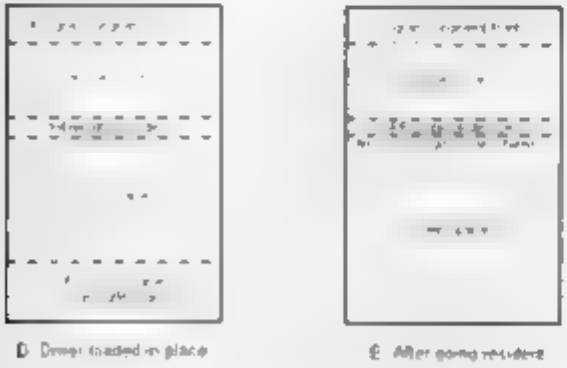
DEVLOD's first job is to move itself out of the way to the top of memory. This lets it load the device driver as low as possible, reducing memory fragmentation. Figures 7-26 and 7-27 diagram the significant steps that DEVLOD takes while running.

Figure 7-26 First Three Steps of DEVLOD Action



Memory maps not to scale

Figure 7-27. Final Stages of DEVLOD Operation



Memory maps not to scale

DEVLOD loads device drivers into memory using the documented DOS function for loading overlays (INT 21H function 4B03h). An earlier version of DEVLOD read the driver into memory using DOS calls to open, read, and close the driver but this made handling EXE driver types difficult. Using the EXEC function instead DOS handles both SYS and EXE files properly. It might appear that the SetDeviceState function 4B05h should be called first to perform SHARE processing but any device driver with this version specific should never be loaded with another version of

DOS. In general, drivers that do not depend on undocumented features of specific versions do not need version tests, so using SETVER amounts in essence to tying down the boiler's safety valve.

DEVLOAD then calls our good friend undocumented INT 21h function 52h to retrieve the address of LAST_DRIVE, a pointer to the DOS Current Directory Structure array, and a pointer to the NUL device. The location of these variables within the SysVars varies with the DOS version number.

DEVLOAD requires a pointer to the NUL device because, as we saw earlier in this chapter when discussing the DEVPROG program, NUL acts as the anchor to the DOS device chain. Since DEVLOAD's whole purpose is to add new devices into this chain, DEVLOAD must update this linked list.

If the DOS version indicates operation under MS DOS 1.x or at the OS/2 compatibility box, DEVLOAD spits out an appropriate message. Otherwise, DEVLOAD creates a pointer to the name field in the NUL device header. Eight bytes at that location are compared to the constant "NUL   ". Even in this test is present only so that the pointer is correct.

In checking over the Appendix notes in this book, the astute reader may have noticed an undocumented DOS function, INT 2Fh AX=1220h, which returns in BX:AX a pointer to the header of the second device driver, NUL, in the chain. Since DOS links together all device driver headers, this effectively gets a pointer to the DOS device chain. So why not call INT 21h Function 52h instead? The reason is that although both functions, INT 2Fh AX=1220h and INT 21h Function 1220h, were meant to be called only from a DOS extender, such as a network redirector, all segment registers set to DOS's kernel segment. You can't access those other variables from SysVars in this case. And you are loading a block device, which you won't know until later, after you've called the driver's INIT routine.

Once DEVLOAD has retrieved this information, it sends the device driver an initialization packet. As we've discussed, the function for Driver Init sends a packet with the INIT command value in the request header and then calls the driver's interrupt routine. The offsets to these routines are stored in the device driver header. DEVLOAD creates a function pointer using the offset for call and sets ES:BX to point to the request header. DEVLOAD merely mimics what DOS does when it loads a device driver.

If the device driver INIT fails, there is naturally nothing we can do but bail out. It is important to note that we haven't yet linked the driver into the DOS device chain, so it's easy to exit. If the driver INIT succeeds, DEVLOAD can then proceed with its true mission, which takes place, oddly enough, in the function Get_Outta.

It is only at this point that DEVLOAD knows whether it was a block or character device driver, so it is here that DEVLOAD takes special actions for block device drivers. In calling Put_Blk_Devs, for example, DEVLOAD first allocates enough memory to create a DOS DPB structure to find the next unused drive letter. Then the function calls INT 21h Function 53h, Translate BPB to DPB, which creates the DOS structure for the new drive and links the new DPB into the DPB chain. These new DPBs are added after the last drive. Logical block devices (such as DPBs, DPB, and CDS) are explained in detail in Chapter 8 of the DOS Technical Reference. The key point is that Put_Blk_Devs DEVLOAD takes information returned by a block device's INIT routine and produces a new DOS drive. This area of the program is also where the most changes in this code occur because DOS 4 added one byte to the DPB, making it too large to fit in the space allowed by the original DEVLOAD code. The result was total system lockup so it was important to merge DEVLOAD to install a block device. This bug has been squashed.

When loading a block device driver, DEVLOAD needs a drive letter to assign to the new driver. As Chapter 8 explains in great detail, the CDS is an undocumented array of structures, sometimes also called the Drive Info Table, which contains the current state of each drive in the system. The array is *n* elements long, where *n* equals LASTDRIVE. DEVLOAD pokes the CDS in order to install a block device driver.

The function Next_Drive is where DEVLOAD determines the drive letter to assign to a block device, if there is an available drive letter. One technique for determining the next letter, #deleted out wrong: DEVLOAD C tries to read the Number of Block Devices field, nblkdrs, out of the List of

lasts. However, this fails to take account of SUBSTed or network redirected drives. Therefore, we instead walk the CDS looking for the first free drive. In any case, DEVLOD updates the nblkdrs field, if it successfully loads a block device.

If the driver being loaded is for a character device, DEVLOD checks two of the device attribute word to determine whether to update the CON and CLOCK$ pointers in the list of I/O. If the character device being installed has its STDIN bit set, the CON pointer is updated to point to the new driver. This pointer is used by DOS to check for CTRL C and CTRL BREAK keystrokes. Similarly, if the CLOCK$ bit is set, the CLOCK$ pointer is changed to reflect the address of the new driver. DOS uses this pointer for all references to the clock device, rather than going through the overhead of searching for it by name. The original version of DEVLOD failed to maintain these two pointers and, as a consequence, DEVLOD/ANSI.SYS would disable Control-C checking. Thanks to Geoff Chappell for letting us know.

After allocating a character device driver, DEVLOD searches all SFTs and CDSs for any references to a driver of the same name. If DEVLOD finds any, it replaces the SFT's pointers to the driver with pointers to the new driver being installed. This is essential to maintaining proper operation of the critical error handlers, as pointed out by Dan Wintermute in the July 1992 issue of *The Dual Journal*, also with comments on the original DEVLOD.COM. Swan Day's code was not completely compatible with DEVLOD. I rewrote it, but the idea remains the same as the one he suggested.

Whether creating a block or character driver, DEVLOD uses the next available byte of the driver's address space that can safely be turned back to DOS for re-use, determined by the lower bit for block devices. Each driver's address has been increased to include the newly created DPBs. Get Out converts the previous last-byte-in-resident-portion paragraphs to be returned.

DEVLOD executes the DOS SYSINIT routine sections to determine whether driver initialization was successful. For character devices, the break address is compared to offset zero in the device segment. If the two are equal, initialization failed. For block devices, the number of units returned in the command packet is checked. If initialization failed, this number is set to zero. DEVLOD also performs any checks made by the device's own initialization routine.

DEVLOD then links the device header into DOS's linked list of device headers. The location copy is recorded. Then, for the last time, just to save the content of the NUL device's link field, DEVLOD copies the link field of the new driver and finally restores its far address. The new driver entry in NUL's chain is fixed. Note again that the DOS linked list is not altered until after you know that the driver's INIT succeeded.

Finally, DEVLOD saves some memory by releasing its environment. The resulting hole in RAM causes no harm, and may help to pop up holes. Utilities and programs successfully loaded resident as this can remain in place. If the second environment segment is not zero, and DEVLOD is not loading the device for the first time, DEVLOD must release the environment. It does so with DOS service INT 21 Function 49h to exit without releasing the memory now occupied by the driver.

DEVLOD.C

Before we look at how the routines listed accomplishes all this in less than 2,900 bytes of executable code, some constraints should be mentioned.

Many of the problems were created by implementing DEVLOD as a COM program using the tiny memory model. The tiny model programs itself up in memory because it's much clearer when the COM loader is forced to provide all segment registers.

In order to make a program work, DOS executing it necessarily has to know every address that the program uses when it's executing. This precludes using any part of the memory supplied with the computer. In the case that's not a serious restriction. Loads executing code are handled with ease; the tiny model language settings take care of the few changes. Data can't be done in C itself.

Borland makes it easy to completely sever the link to the runtime libraries. They provide sample code showing how to do so. Microsoft also provides such a capability, but its documentation is quite cryptic. Any of the Borland compilers for DOS can be used. The first version of DEVLOD was created under Turbo C, while the current version was done with Borland C++ 3.0 used in Turbo C mode.

The DOS program as presented requires either Borland or Turbo C with its register pseudo variables, geninterrupt, and emit features. As explained in Chapter 2, register pseudo variables such as _AX provide a way to directly read or load the CPU registers from C. Both geninterrupt and emit supply emit bytes into the code stream; neither are actually functions.

Figure 7-28 shows the main program DEVLOD.C.

Figure 7-28. The DEVLOD.C Program

```
/*****************************************************************
*    DEVLOD.C - Jim Kyle - 08/20/90                              *
*      Copyright 1990,1992 by Jim Kyle - All Rights Reserved     *
*    (minor revisions by Andrew Schulman - 9/12/90)              *
*    (major rewrite by Jim Kyle - July-Aug 1992)                 *
*    (minor change by Jim Kyle - August 1993)                    *
*    Dynamic loader for device drivers                           *
*          Requires Turbo C or BC++, see DEVLOD.MAK also.        *
*****************************************************************/
#include <stdio.h>
#include <stdlib.h>
#include <dos.h>

#include  "undocdos.h"   /* defines DOS internal structures      */

#define GETFLAGS __emit__(0x9F)
#define fixDS    __emit__ 0x16,0x1F)    /* PUSH SS, POP DS      */
#define PUSH_BP  __emit__(0x55)
#define POP_BP   __emit__(0x5D)
#define GO_DOS   geninterrupt( 0x21 )

unsigned _stklen = 0x200,
unsigned _heaplen = 0;

LPPSP PSPptr,              /* used to access fields of the PSP     */
char  FileName[65],        /* filename global buffer               */
char  * dvrarg,            /* points to char after name in cmdline */
WORD  movsize,             /* number of bytes to be moved up       */
void  (far * driver)();    /* used as pointer to call driver code  */
LPDDVR drvptr,             /* holds pointer to device driver       */
LPDDVR NULptr,             /* pointer to NUL device (chain start)  */
FP    nuldrvr;             /* additional driver pointers           */
FP    nxtdrvr,
BYTE  far * nblkdrs,       /* points to block device count in List */
WORD  lastdrive,           /* value of LASTDRIVE in List of Lists  */
BYTE  far * CDSbase,       /* base of Current Dir Structure        */
int   CDSsize,             /* size of CDS element                  */
WORD  nu_seg,              /* hold parts of ListOfLists pointer    */
WORD  nu_ofs,
WORD  cds_ofs,
LPLOL LOLptr,
DOSCMDPKT CmdPkt,
int SFT_size,              /* used by new FixSFT, set by GetList   */

extern unsigned _psp;              /* established by startup code  */
extern unsigned _heaptop,          /* established by startup code  */
extern BYTE _osmajor,              /* established by startup code  */
extern BYTE _osminor;              /* established by startup code  */
void _exit( int ),                 /* established by startup code  */
void abort( void );                /* established by startup code  */
```

```
void movup( LPPSP, FP, int );   /* in MOVUP.ASM                    */

int  TestName( LPDDVR, LPSFT ), /* in TESTNAME.ASM for FixSFT      */
void ChgSFT( LPSFT, LPDDVR ),   /* in TESTNAME.ASM for FixSFT      */

void copyptr( FPP src, FPP dst )        /* copy far pointer        */
{ *dst = *src; }

void exit(int c)        /* called by startup code's sequence       */
{ _exit(c);}

void Put_Msg ( char *msg )  /* replaces printf(), uses DOS only    */
{ _AH = 2;              /* doesn't need to be inside loop          */
  while (*msg)
  { _DL = *msg++;
    GO_DOS,
  }
}

BOOL Get_Driver_Name ( void )
{ char *nameptr,
  int i, j, cmdlinesz;

  nameptr = (char *)&(PSPptr->Tailc);   /* set up to parse         */
  cmdlinesz = *nameptr++;
  if (cmdlinesz < 1)        /* if nothing there, return FALSE      */
    return FALSE,
  for (i=0; i<cmdlinesz && nameptr[i]<'!', i++) /* skip blanks      */
    ;
  dvrarg = (char *)&nameptr[i]; /* save to put in SI               */
  for ( j=0, i<cmdlinesz && nameptr[i]>' ', i++)  /* copy name      */
    FileName[j++]   nameptr[i],
  FileName[j] = '\0',    /* name copied, but good time to          */
  for (, i<cmdlinesz && nameptr[i]>' ', i++)   /*  make all UC      */
    if( nameptr[i] >= 'a' && nameptr[i] <= 'z' )
      nameptr[i] &= 0x5F;                   /* take out case bit   */
  return TRUE;          /* and return TRUE to keep going           */
}

void Err_Halt ( char *msg )     /* print message and abort         */
{ Put_Msg ( msg ),
  Put_Msg ( "\r\n" ),           /* send CR,LF                      */
  abort(),
}

void Move_Loader ( void )       /* vacate lower part of RAM        */
{ WORD movsize, destseg;
  movsize = _heaptop - _psp;    /* size of loader in paragraphs    */
  destseg = PSPptr->Nxtgref;    /* end of memory                   */
  movup ( PSPptr, MK_FP( destseg - movsize, 0 ),
          movsize << 4);        /* move and fix segregs            */
}

void Load_Drvr ( void )         /* load driver file into RAM       */
{ WORD handle,
  struct {
    WORD LoadSeg,
    WORD RelocSeg,
  } ExecBlock,

  ExecBlock.LoadSeg = _psp + 0x10;
  ExecBlock.RelocSeg = _psp + 0x10;
  _DX = (WORD)&FileName[0],     /* ds:dx point to filename         */
  _BX = (WORD)&ExecBlock,       /* es:bx point to ExecBlock        */
```

```
  _ES = _SS;                    /* which, being local, is SS    */
  _AX = 0x4B03;                 /* load overlay (COM, SYS, EXE) */
  GO_DOS;                       /* DS is okay on this call      */
  GETFLAGS;                     /* check what happened          */
  if ( _AH & 1 )                /* if carry flag set...         */
    Err_Halt ( "Unable to load driver file." );
}

void Get_List ( void )          /* set up pointers via List     */
{ _AH = 0x52;                   /* find DOS List of Lists       */
  GO_DOS;
  nulseg = _ES;                 /* DOS data segment             */
  LoLofs = _BX;                 /* current drive table offset   */
  LOLptr = (LPLOL)MK_FP( nulseg, LoLofs );

  switch( _osmajor )            /* NUL adr varies with version  */
    {
    case  0:
      Err_Halt ( "Drivers not used in DOS V1." );
    case  2:
      nblkdrs = (FP)0L;
      lastdrive = (LOLptr->ver.v2.lastdrv);
      NULptr = (LPDDVR)&(LOLptr->ver.v2.nul);
      nulofs = (WORD)NULptr;    /* just the offset part         */
      SFT_size = 0x2B;
      break;
    case  3:
      if (_osminor == 0)
      {
          nblkdrs = (BYTE far *)&(LOLptr->ver.v30.blk_dev);
          lastdrive = (LOLptr->ver.v30.lastdrv);
          NULptr = (LPDDVR)&(LOLptr->ver.v30.nul);
          nulofs = (WORD)NULptr;        /* just the offset part */
          SFT_size = 0x38;
      }
      else
      {
          nblkdrs   (BYTE far *)&(LOLptr->ver.v31up.blk_dev);
          lastdrive = (LOLptr->ver.v31up.lastdrv);
          NULptr = (LPDDVR)&(LOLptr->ver.v31up.nul);
          nulofs = (WORD)NULptr;        /* just the offset part */
          SFT_size = 0x35;
      }
      CDSbase   (BYTE far *)(LOLptr->ver.v31up.cds);
      CDSsize   sizeof( CDS );  /* defined for DOS3.1 struct    */
      break;
    case  4:
    case  5:
    case  6:
      nblkdrs   (BYTE far *)&(LOLptr->ver.v31up.blk_dev);
      lastdrive = (LOLptr->ver.v31up.lastdrv);
      NULptr = (LPDDVR)&(LOLptr->ver.v31up.nul);
      nulofs   (WORD)NULptr;            /* just the offset part */
      CDSbase = (BYTE far *)(LOLptr->ver.v31up.cds);
      CDSsize = sizeof( CDS ) + 7;      /* V4,5 7 bytes bigger  */
      SFT_size = 0x3B;
      break;
    case 10:
    case 20:
      Err_Halt ( "OS2 DOS Box not supported." );
    default:
      Err_Halt ( "Unknown version of DOS!" );
    }
}
```

```
void Fix_DOS_Chain ( void )     /* patches driver into DOS chn  */
{ WORD i,

  nuldrvr = MK_FP( nul.seg, nulofs+0x0A ),       /* verify drvr  */
  drvptr = "NUL     ",
  for ( i=0; i<8, ++i )
    if ( *((BYTE far *)nuldrvr+i) != *((BYTE far *)drvptr+i) )
      Err_Halt ( "Failed to find NUL driver." );

  nuldrvr = MK_FP( nu seg, nulofs ),     /* point to NUL driver  */
  drvptr  = MK_FP( _psp+0x10, 0 ),       /* new driver's address */

  copyptr( (FP)nuldrvr, (FP)&nxtdrvr ), /* hold old head now     */
  copyptr( (FP)&drvptr, (FP)nuldrvr ),  /* put new after NUL     */
  copyptr( (FP)&nxtdrvr, (FP)drvptr );  /* and old after new     */
}

// returns number of next free drive, -1 if none available
int Next_Drive ( void )
{
#ifdef USE_BLKDEV
  return (nblkdrs && (*nblkdrs < lastdrive)) ? *nblkdrs   -1,
#else
  /* This approach takes account of SUBSTed and network-redirector
   * drives by finding the first unused entry in the CDS structure
   */
  LPCDS cds,
  int i=0;
  for ( cds=(LPCDS CDSbase,      /* start at front of struct      */
        i<lastdrive;             /* go all way through it         */
        i++, ((BYTE far *)cds)+=CDSsize)        /* count up       */
    if (! cds->flags)            /* found a free drive            */
        break,
  return (i == lastdrive) ? -1   i,      /* return number, or -1 */
#endif
}

/*  This routine initializes the device driver and returns TRUE
 *  if all went well   If initialization fails for any reason,
 *  this function returns FALSE and the driver will not be linked
 *  into the chain maintained by DOS.
 */
BOOL Init_Drvr ( void )
{ WORD tmp;
  drvptr  = MK_FP( _psp+0x10, 0 ),       /* new driver's address */
  CmdPkt command = DD_INIT,      /* defined in UNDOCDOS H file   */
  CmdPkt hdrlen = sizeof( DDCMDPKT );
  CmdPkt.unit = 0;
  CmdPkt status   0,             /* clear status just in case    */
  CmdPkt inpofs = (WORD)drvarg, /* points into command line      */
  CmdPkt inpseg = _psp,
  CmdPkt NextDrv = (BYTE)Next_Drive();  /* for block dev init    */
  if( CmdPkt NextDrv == 0xFF &&
      ((drvptr->attr & CHAR_DEV) == 0))
    { Put_Msg(  Current Directory Structure is full, cannot install." ),
      return FALSE,
    )

 if (_osmajor >= 5)
    { /* In DOS 5+, DOS passes the device driver irEndAddress
         (see DOS Programmer's Reference, p. 400) */
      CmdPkt.brkofs = 0;
      CmdPkt brkseg  0xA000,                    /* allow all RAM */
    )
```

```
  tmp = drvptr->stratofs,       /* STRATEGY pointer in driver   */
  driver = MK_FP( FP_SEG( drvptr ), tmp ),
  _ES = FP_SEG( (void far *)&CmdPkt ),
  _BX = FP_OFF( (void far *)&CmdPkt );
  (*driver)();                  /* set up the packet address    */

  tmp = drvptr->introfs,        /* INTERRUPT pointer in driver  */
  driver = MK_FP( FP_SEG( drvptr ), tmp );
  (*driver)();                  /* do the initialization        */

   * In the first edition version of DEVLOD, this function checked
   * the status code in the command packet to determine whether the
   * installation had failed.  Actually, the status code is NOT
   * checked by DOS itself!  Thanks to Geoff Chappell for pointing
   * out that SYSINIT does not check the status returned by drivers
   * after initialization.  A block device driver is not retained if
   * its unit count is found to be zero, while a character device
   * should set its break address to offset 0 in its load segment.
   *;
  return( drvptr->attr & CHAR_DEV ?
          MK_FP(CmdPkt.brkseg,CmdPkt.brkofs) != MK_FP(FP_SEG(drvptr), 0) :
          CmdPkt.nunits != 0 );
}

/*  This routine looks far more complicated than it actually is.
 *  It's used only when block device drivers are being installed,
 *  and does the housekeeping of DPBs and CDS entries that such
 *  device requires.  Major changes were made here in the second
 *  edition of the program, to accomodate changes in DPB size that
 *  happened at Version 4.0 but went unnoticed until DOS5 appeared.
 *  Special thanks are due Dan B. Wright, Nathaniel Polish, and
 *  Geoff Chappell for spotting problem areas here.
 *
 *  This routine returns FALSE if all goes well, or TRUE if any
 *  error condition is detected.
 *
BOOL Put_Blk_Dev ( void )
{ int newdrv,
  int i;
  int retval = TRUE;        /* pre-set for failure              */
  int BufferSize,
  int unit = 0;
  LPDPB oldDPB, newDPB, endmark   (LPDPB)0xFFFFFFFFL,
  LPCDS cds,
  LPDDVR newdrvr    (LPDDVR)MK_FP( _psp+0x10, 0 ),

  if ((Next_Drive() == -1) || CmdPkt.nunits == 0)
    return retval;              /* cannot install block driver  */
   * (CmdPkt.brkofs !=  0)      /* align to next paragraph      */
  {
    CmdPkt.brkseg += (CmdPkt.brkofs >> 4) + 1;
    CmdPkt.brkofs = 0;
  }
  while  CmdPkt.nunits-- )  /* repeat this loop for each unit   */
  {
    if ((newdrv = Next_Drive()) == -1)
      return TRUE,      /* no room for another drive, quit      */
    if( nblkdrs )               /* if not a null pointer,       */
      (*nblkdrs)++;             /* ...tally into drive counter  */

#ifdef ORIGINAL
    /*  Tell DOS to get the DPB of the last drive in CDS.  This
     *  technique, used in the first version of DEVLOD, creates a
     *  problem if the final drive is a JOINed or SUBSTed entry in
     *  the list.  The alternate method of finding the last DPB is
```

```
     *  not subject to this problem, but may be a bit slower   The
     *  address of the last drive DPB is saved in  oldDPB"
     */
    _AH = 0x32;          /* get DPB of last drive in CDS          */
    _DL = newdrv,
    GO_DOS;
    _AX = _DS,           /* save segment to make the pointer      */
    FIXDS,
    oldDPB = MK_FP(_AX, _BX),   /* this is base address of DPB    */
#else
    /*  Trace out entire chain each time around the loop.  While
     *  this is possibly slower than the original method, it will
     *  not be deceived by CDS entries   The address of the last
     *  DPB is saved in 'oldDPB'   Note that only the offset words
     *  of the link pointers are compared, DOS itself does not put
     *   endmark" in the segment word, although this routine does
     */
    oldDPB = LOLptr->dpb,        /* always start at first DPB     */
    if (_osmajor < 4)            /* trace through to the end      */
      while( (WORD)oldDPB->ver.v3.next != (WORD)endmark )
        oldDPB = oldDPB->ver.v3.next,
    else
      while( (WORD)oldDPB->ver.v4.next != (WORD)endmark )
        oldDPB = oldDPB->ver.v4.next,
#endif

    /*  Tell  DOS to create the DPB, passing it BPB info from a
     *  list of near pointers passed back by the driver   Note
     *  that DS must be set after all memory references are done,
     *  because it's used to access the globals   Similarly, AX
     *  must be set after all segment registers, because it is
     *  used to load the segreg
     */
    newDPB = (LPDPB)MK_FP( CmdPkt.brkseg, 0 ),
    _SI = * WORD far *)MK_FP(CmdPkt.inpseg, CmdPkt.inpofs);
    _ES = CmdPkt.brkseg,         /* ES BP is DPB address to use   */
    _DS = CmdPkt.inpseg;         /* DS SI is adr of BPB to read   */
    PUSH_BP,                     /* save stack-frame pointer      */
     BP = 0;                     /* BPB offset value              */
    _AH   0x53,                  /* build the DPB for this unit   */
    GO_DOS,
    POP_BP;                      /* restore stack-frame pointer   */
    FIXDS,

    /*  Check to be sure that block sector size is acceptable
     *  If bigger than BUFFERS were built for, refuse to install
     *  the driver      No such check was made in the original
     *  version of this program  Geoff Chappell spotted the omission.
     */
    switch(  osmajor )           /* get BUFFERS size from LOL     */
    {                            /* location in LOL will vary...  */
    case  2:
      BufferSize = LOLptr->ver.v2.secsiz,
      break,
    case  3:
      if ( _osminor == 0)
        BufferSize = LOLptr->ver.v30.secsiz;
      else
        BufferSize = LOLptr->ver.v31up.secsiz;
      break,
    case  4:
    case  5:
      BufferSize = LOLptr->ver.v31up.secsiz;
      break,
    default
```

```
      Err_Halt ( "Unknown version of DOS!"),
    }
    if( newDPB->bytes_per_sect > BufferSize )
      return TRUE;                      /* get out if too big   */

    /*  Now set the DPB address into the old last DPB's link
     *  address field ("next" pointer).
     */
    if (_osmajor < 4)                   /* link new DPB to chain        */
      oldDPB->ver.v3.next = newDPB,
    else
      oldDPB->ver.v45.next = newDPB;

    /*  Set up the Current Directory Structure for this drive and
     *  tag it as a physical drive   Clear IFS area if DOS V4 or
     *  higher
     */
    if (_osmajor > 2)                   /* Version 2 did not use CDS    */
      { cds = (LPCDS)(CDSbase + (newdrv * CDSsize));
        cds->flags = CDS_PHYS,  /* defined in UNDOCDOS.H file   */
        cds->dpb   newDPB,      /* set DPB adr into CDS         */
        cds->ifs_loc.start_cluster = 0xFFFF, /* not accessed yet */
        cds->ifs_loc.ffff = -1L,
        cds->slash_offset   2,  /* start in root directory      */
        if (_osmajor > 3)       /* zero out IFS stuff           */
          { *((WORD far *)(&(cds->slash_offset))+1) = 0,
            *((WORD far *)(&(cds->slash_offset))+2) = 0,
            *((WORD far *)(&(cds->slash_offset))+3) = 0,
            *((BYTE far *)(&(cds->slash_offset))+8) = 0,
          }
      }

    /*  Finally, set up pointers for the DPB and the driver so
     *  that they can find each other, and adjust space
     *  reservations so that the DPB won't be wiped out upon
     *  return to DOS   Step the DPB list pointer in case the
     *  driver has multiple units.
     */
    newDPB->drive   newdrv,     /* set in drive number          */
    newDPB->unit   unit++,      /* and also the unit number     */
    if ( osmajor < 4)           /* Versions 2 and 3 are alike   */
      { newDPB->ver.v3.driver = newdriver,
              newDPB->ver.v3.next = endmark,
        CmdPkt brkseg += 2,     /* was 32 bytes, exact fit      */
      }
    else                        /* Versions 4 and 5 are alike   */
      { newDPB->ver.v45.driver = newdriver,
        newDPB->ver.v45.next = endmark,
        CmdPkt brkseg += 3;     /* 33 bytes each now            */
      }
    CmdPkt inpofs += 2,         /* point to next DPB pointer    */
  }                             /* end of nunits loop           */
  return FALSE;                 /* all went okay                */
}

/*  This function is called for a character driver only  It searches
 *  every entry in the SFT, looking for any reference to the named
 *  driver, and if such a reference is found, modifies 6 bytes in the
 *  SFT entry to point to the just-added new driver  This is necessary
 *  for proper operation of the critical error handler. It is based on
 *  code by Dan Winter, published in the July, 1992 issue of Dr  Dobb's
 *  Journal, but Dan's original code was not compatible with DEVLOD.
 *
 *  SFT size is established by the GetList() function earlier.
 */
```

```
void FixSFT ( void )
{ LPSFTB blk, next_blk,          /* use typedefs for simplicity  */
  LPSFT sft;
  WORD num_items;

  for( next_blk = LOLptr->sft;          /* first SFT block       */
       (WORD)next_blk != 0xFFFF, )      /* check all blocks      */
    { blk = next_blk;                   /* start this block      */
      next_blk = blk->next;             /* link for next one     */
      num_items = blk->here,            /* get size of block     */
      sft = &(blk->first);              /* first SFT in it now   */
      while( num_items-- > 0 )          /* test all items here   */
        { if( sft->var.v2.nusers )      /* is this SFT in use?   */
            if( TestName( drvptr, sft ))        /* yes, match?   */
              ChgSFT( sft, drvptr );    /* yes, fix the pointer  */
          (char far *)sft += SFT_size;  /* to next item in list  */
        }
    }
}

/*  This function is called only when the driver has been fully
 *  installed with no detected errors.  If the driver is a block
 *  device, Put_Blk_Dev() is called to create its drive letter
 *  and CDS and DPB structures, otherwise the CON and CLOCK$
 *  pointers in the List of Lists are updated as applicable.  If
 *  the block device installation fails, DEVLOD quits without
 *  linking the driver into the DOS chain.  Otherwise this driver
 *  is put at the head of the chain right after NUL, and the program
 *  returns to DOS, leaving the driver resident.  In either case,
 *  this function will never return to the main() procedure
 */
void Get_Out ( void )
{ WORD temp;

  temp = drvptr->attr;              /* attribute word              */
  if( (temp & CHAR_DEV) == 0 )      /* if block device, set up this */
    { if( Put_Blk_Dev() )           /* fails if cannot do so       */
        Err_Halt( "Could not install block device" ),
    }
  else                              /* not block, check for updates */
    { if( (temp & IS_STDIN) )
      LOLptr->con = drvptr,         /* this is for CTRL C checking  */
      else if( (temp & IS_CLOCK) )
      LOLptr->clock = drvptr;       /* this is for fast time access */
      FixSFT();                     /* Dan Winter's fix for SFT     */
    }

  Fix_DOS_Chain(),                  /* all okay so patch into DOS   */

  _ES = PSPptr->EnvSeg,             /* release environment space    */
  _AH = 0x49;
  GO_DOS,
  PSPptr->EnvSeg = 0,               /* zero out the address in PSP  */

  /* then set up regs for KEEP function, and go resident          */
  temp = (CmdPkt brkofs + 15),      /* normalize the offset         */
  temp >>= 4,
  temp += CmdPkt brkseg,            /* add the segment address      */
  temp -= _psp;                     /* convert to paragraph count   */
  _DX = (WORD)temp;                 /* paragraphs to retain         */
  _AX = 0x3100;                     /* KEEP function of DOS         */
  GO_DOS,                           /* won't come back from here!   */
}

void main( void )                   /* usual argc, argv not used!   */
```

```
{ PSPptr = (LPPSP)MK_FP( _psp, 0 );     /* create global ptr    */
  if( !Get_Driver_Name() )
    Err_Halt( "Device driver name required.");
  Move_Loader(),                        /* move code high and jump      */
  Load_Drvr(),                          /* bring driver into freed RAM  */
  Get_List(),                           /* get DOS internal variables   */
  if(Init_Drvr())                       /* let driver do its thing      */
      Set_Out(),                        /* check init status, go TSR    */
  else
      Err_Halt( "Driver initialization failed." );
}
```

MOVUP.ASM

The small assembly language module MOVUP (Figure 7-29) contains only one function, movup(). Recall that in order not to fragment memory, DEVLOD moves itself up above the area into which it loads the driver. The program accomplishes this feat with movup().

Figure 7-29. MOVUP.ASM

```
        NAME    movup
;[]------------------------------------------------------------[]
;|      MOVUP.ASM -- helper code for DEVLOD.C                   |
;|      Copyright 1990 by Jim Kyle - All Rights Reserved        |
;[]------------------------------------------------------------[]

_TEXT   SEGMENT BYTE PUBLIC 'CODE'
_TEXT   ENDS

_DATA   SEGMENT WORD PUBLIC 'DATA'
_DATA   ENDS

_BSS    SEGMENT WORD PUBLIC 'BSS'
_BSS    ENDS

DGROUP  GROUP   _TEXT, _DATA, _BSS

ASSUME  CS:_TEXT, DS:DGROUP

_TEXT   SEGMENT BYTE PUBLIC 'CODE'

;-------------------------------------------------------
;       movup( src, dst, nbytes )
;       src and dst are far pointers, area overlap is NOT okay
;-------------------------------------------------------
        PUBLIC  _movup

 movup  PROC    NEAR
        push    bp
        mov     bp, sp
        push    si
        push    di
        lds     si,[bp+4]               ; source
        les     di,[bp+8]               ; destination
        mov     bx,es                   ; save dest segment
        mov     cx,[bp+12]              ; byte count
        cld
        rep     movsb                   ; move everything to high ram
        mov     ss,bx                   ; fix stack segment ASAP
        mov     ds,bx                   ; adjust DS too
        pop     di
        pop     si
        mov     sp, bp
        pop     bp
        pop     ds                      ; Get return address
```

```
        push    bx                      ; Put segment up first
        push    dx                      ; Now a far address on stack
        retf
_movup  ENDP

_TEXT   ENDS

        end
```

TESTNAME.ASM

New in this modified version is the assembly file TESTNAME.ASM (Figure 7-30), which provides two small routines that greatly simplify the DOS SFT patching procedure described by Dan Writer in his July, 1992 letter to *The Dobbs Journal*. TestName() takes far pointers to the new driver and to the current SFT entry; it then compares the 8-byte name fields, returning one if all eight bytes match and zero otherwise. ChgSFT() takes the same two far pointers and corrects the affected fields of the SFT entry to reflect the new driver's address.

Figure 7-30. TESTNAME.ASM

```
;-------------------------------------------------------------------
;       int TestName( LPDDVR, LPSFT )
;       src and dst are far pointers, TRUE if 8-byte match found
;-------------------------------------------------------------------
        PUBLIC  _TestName

_TestName       PROC    NEAR
        push    bp              ; save regs
        mov     bp,sp
        push    si
        push    di
        push    ds
        lds     si,[bp+4]       , get pointer to driver header
        add     si,10           , offset to name field
        les     di,[bp+8]       , pointer to SFT start
        add     di,32           , offset to name field
        mov     cx,8            , name length
        cld
        repz    cmpsb           , go while equal
        mov     al,[si-01]      , last chars tested
        sub     al,[es.di-01]
        add     al,0FFh         , CY if nonzero
        sbb     al,al           ; 0 or FF
        inc     al              , 1 if match, else 0
        pop     ds
        pop     di
        pop     si
        pop     bp
        ret
_TestName       ENDP

;-------------------------------------------------------------------
;       void ChgSFT( LPSFT, LPDDVR )
;       Modifies SFT to point to new driver
;-------------------------------------------------------------------
        PUBLIC  _ChgSFT

_ChgSFT PROC    NEAR
        push    bp              ; save regs
        mov     bp,sp
        push    di
        les     di,[bp+4]       ; get SFT address into ES:DI
        add     di,7            ; offset to v.type.devdvr field
        mov     ax,[bp+8]       ; offset of LPDDVR
```

```
        mov     dx,[bp+10]      ; segment of LPDDVR
        cld
        stosw                   ; store offset
        xchg    ax,dx
        stosw                   ; store segment
        xchg    ax,dx
        stosw                   ; store offset
        pop     di
        pop     bp
        ret
_ChgSFT ENDP
```

Both of these functions normally would be more easily done using C library functions such as [illegible], but DEVLOD's need to use far pointers with near procedures made it much easier to perform the tasks in assembly language by building the field offsets into this code. I was also able to [illegible] a number of places dealing with confusing casts, although at least one remains in the LASTDRIVE extension of DEVLOD. To access the SFT chain prior to DOS 4, it is necessary to cast the SFT pointer to char far * before adding the table size.

C0.ASM

The [illegible] version of C0.ASM which has been extensively modified from start-up code provided with [illegible] C. The assembler code forms part of every C program and provides the link address between the DOS command line and the C program itself. Normal start-up code, however, does not [illegible] the stripped-down environment. This code parses the argument list, sets up pointers to the [illegible] arguments [illegible] so that library functions can operate. It also arranges for automatic [illegible] of the memory. These services were DEVLOD cannot tolerate.

Normally, a program is responsible for removal of these actions, but C0.ASM installs them. When a program [illegible] DOS, it returns to the RAM resident by the program down to the next [illegible]. The [illegible] pushes the returned value onto the stack and calls exit. Exit [illegible] the stack, discovers the [illegible] and returns from main.

The [illegible] functions is performed. This module establishes global variables [illegible] major [illegible] and type of which DEVLOD keeps track of operation. Values for these variables are [illegible] DOS itself, [illegible] and stored in the variables before control passes to main.

[illegible] C0.ASM routine is also concerned with establishing an environment within which DEVLOD can [illegible] with the actual objectives of DEVLOD itself. We've omitted its listing for the sake of brevity, but the source and the OBJ file are included on the companion diskette, however.

Make File

Since this sample program includes two assembly language modules in addition to the C source, a MAKE file [illegible] compilation. Figure 7-31 shows one for use with Borland's MAKE utility.

Figure 7-31 The DEVLOD Makefile

```
# makefile for DEVLOD.COM   created 05/25/90 - jk
#                           last revised 08/20/92 - jk
# can substitute other assemblers for TASM, TCC for BCC

AS = D:\BC\BIN\TASM
CC = D:\BC\BIN\BCC
CL = D:\BC\BIN\TLINK

devlod.com      devlod.obj c0.obj movup.obj testname.obj
        $(CL) c0 movup testname devlod /c/m/t,devlod.com

c0.obj  :       c0.asm
```

```
        $(AS) c0 /t/mx/la;

movup.obj:      movup.asm
        $(AS) movup /t/mx/la;

testname.obj:   testname.asm
        $(AS) testname /t/mx/la;

devlod.obj:     devlod.c
        $(CC)  c -ms -Fo devlod.c
```

You do, of course, need to change the three macro definitions to reflect the drive and path for your own compiler installation. Then you can simply type "MAKE -FDEVLOD.MAK". The -r option switch is included in the LINK command and ensures that the linker generates a .COM file, rather than the more usual .EXE format.

How Well Does DEVLOD Work?

A fitting conclusion to this chapter is to use some of the utilities developed earlier (UDMEM and DEV) to see what my system looks like after I've loaded up a couple of device drivers with DEVLOD. The report is shown in Figure 7.32.

Figure 7.32. Testing DEVLOD

```
D:\UDOS2\CHAP7> devlod c:\ramdrive.sys 512 /e

Microsoft RAMDrive version 3.06 virtual disk E:
    Disk size: 512k
    Sector size: 512 bytes
    Allocation unit: 1 sectors
    Directory entries: 64

D:\UDOS2\CHAP7> devlod c:\ansi-uv.sys

D:\UDOS2\CHAP7> udmem
Seg     Owner   Size
0253    0008    092A (  37536)   DOS Data Segment
          Seg  Size Type
          ---- ---- ------ ---------
          0254 0041 Device Driver (386MAX)
          0296 0015 Device Driver (386LOAD)
          02AC 0741 Device Driver  SSTORDRV) [26 FA FE ]
          09EE 0015 Device Driver (386LOAD)
          0A04 0050 System File Tables
          0A62 0005 FCBs
          0A68 0020 Buffers
          0A89 0037 CDS Table
          0AC1 00BC Stacks [02 0A 0B 0C 0D 0E 70 72 73 74 76]
0B7E    0008    0004 (     64)   DOS Code area
0B83    0B84    0010 (    256)   Env at 0B14
0B94    0000    0005 (     80)   Free
0B9A    0B9B    0147 (   5232)   No Env Segment  /f:2048 /l 20
0CE2    0CEF    000B (    176)
0CEE    0CEF    0010 (    256)   Env at 0A36
0CFF    0DDF    000B (    176)
0D0B    0000    0001 (     16)   Free
0D0D    0D0E    005A     1440)   No Env Segment  c:\ramdrive.sys 512 /E
0D68    0D69    0075     1872)   No Env Segment  c:\ansi-uv.sys [1B 29 2F ]
0D0E    0DDF    1268 ( 75392)   Env at 0D00    D  UDOS2\CHAP7 UDMEM.EXE  [0D E5 F7 F8 ]
2D47    0000    7FB7 (523120)   Free [30 E6 E9 EC EF F4 F5 F9]
9FFF                            End of conventional RAM
        UMB Chain
C800    FFFF    05BE ( 22752)   386LOADed Driver [13 15 28 ]
CD8F    FFFA    0004 (     64)   386MAX UMB control block
```

```
C094    FFFE    0205 (  8272)   386MAX UMB
C09A    FFFA    0004 (    64)   386MAX UMB control block
C09F    FFFE    0022 (   544)   386MAX UMB
C0C2    FFFA    0004 (    64)   386MAX UMB control block
C0C7    FFFE    0022 (   544)   386MAX UMB
C0EA    FFFA    0004 (    64)   386MAX UMB control block
C0EF    FFFE    0042 (  1056)   386MAX UMB
D032    FFFA    0004 (    64)   386MAX UMB control block
D037    FFFE    0210 (  8448)   386MAX UMB
D248    FFFA    0004 (    64)   386MAX UMB control block
D24D    FFFE    00C0 (  3072)   C:\4D4\4DOS.COM [2E ]
D30E    FFFA    0004 (    64)   386MAX UMB control block
D313    FFFE    0020 (   512)   386MAX UMB
D334    D33C    0006 (    96)
D338    D33C    04CD ( 19664)   Env at 080A    C:\UV\UV.COM [10 ]
D809    D33C    0002 (    32)
D80C    D814    0006 (    96)   [20 21 27 ]
D813    D814    01A0 (  6864)   Env at 09C2    D:\UTILS\CTRLALT.COM  [08 09 ]
D9C1    D814    0002 (    32)
D9C4    FFFA    0004 (    64)   386MAX UMB control block
D9C9    FFFE    0066 (  1632)   386MAX UMB [27 23 24 ]
DA30    FFFA    0004 (    64)   386MAX UMB control block
DA35    FFFE    0020 (   512)   386MAX UMB
DA56    0000    05A8 ( 23168)   free
DFFF    FFFD    1200 ( 73728)   386MAX locked-out area
F200    FFFF    0059 (  1424)   386LOADed Driver
F25A    0000    05A4 ( 23104)   free
F7FF    FFFD    0400 ( 16384)   386MAX locked-out area
FC00    FFFF    00AD (  2768)   386LOADed Driver [4D 67 ]
FCAE    FCB6    0006 (    96)
FCB5    FCB6    0042 (  1056)   Env at FCF9    C:\4D4\KSTACK.COM       [96 ]
FCF8    FCB6    0002 (    32)
FCFB    0000    0004 (    64)   free
FD00                            End of UMB Chain

D:\UDOS2\CHAP7> dev
NUL
CON
Block: 1 unit(s)
CON
Block: 1 unit(s)
CACHE$$$
386MAX$$
EMMXXXX0
CON
AUX
PRN
CLOCK$
Block: 3 unit(s)
COM1
LPT1
LPT2
LPT3
COM2
COM3
COM4
```

In Figure 7-32, the output from LDMEM shows quite clearly that my device drivers really are resident in memory. Meanwhile, the output from DEV confirms that they are linked into the DOS device chain. For example, the first "CON" is ANSI_UV.SYS and the next block device is RAMDRIVE.SYS. Of course, the real test is that after loading RAMDRIVE.SYS and ANSI_UV.SYS, I had an additional drive created by RAMDRIVE.SYS, programs that assumed the presence of ANSI.SYS suddenly started producing reasonable output. And, of course, I had somewhat less memory

It should be noted that some device drivers appear not to be properly loaded by DEVLOD. These include some memory managers and drivers that use extended memory. For example, Microsoft's XMS driver HIMEM.SYS often crashes the system if you attempt to load it with DEVLOD. (This is amazing, considering that HIMEM.SYS, if installed, is documented to require loading before any other memory manager.)

Furthermore, while DEVLOD/VDISK.SYS demands works in that a valid RAM disk is created, other programs that check for the presence of VDISK, such as protected-mode DOS extenders, often fail mysteriously when VDISK has been loaded in this unusual fashion. Again, VDISK is such an ill-behaved program that Microsoft lists it as being incompatible with Windows 3.1 under any circumstances, so discrepancies are to be expected.

Jay Lowe has reported that a Trantor SCSI driver appears to load through DEVLOD without any detected errors, but that attempts to access the associated drive fail as if the driver were not there. Other, more mysterious problems seem to be somewhere. However, in the vast majority of cases DEVLOD should give you no problems. The few cases we've run across that give trouble represent a limited cross-section of the vast array of device drivers.

For a better perspective on loading drivers, see the article by Chris Todd, "Installing MS-DOS Device Drivers from the Command Line," published in the British magazine *PAT*, August 1989. For background on DOS device drivers in general, two excellent books are the classic *Writing MS-DOS Device Drivers* (Second Edition by Robert S. Lai; Reading, MA: Addison-Wesley, 1992) and *Writing DOS Device Drivers in C* (by Phillip M. Adams and Glenn E. Lourbe; Englewood Cliffs, NJ: Prentice Hall, 1990).

Many of the complexities of loading block devices—in particular, the importance of updating the CDS—become clear in the next chapter, where we discuss the DOS file system.

CHAPTER 8

The DOS File System and Network Redirector

by Jim Kyle, David Maxey, and Andrew Schulman

The file system is an almost inseparable part of MS-DOS. While most successful PC software bypasses many of DOS's services and goes directly to the hardware to produce screen output or read the keyboard, few programs ignore the DOS file system when it comes to reading and writing files. Even software like Microsoft's 32-bit 386 mode Windows for Workgroups (WfW) 3.11 and "Chicago" (DOS 7/Windows 4) which bypasses the file system code in MS-DOS, still closely emulate the behavior of DOS.

Actually, there are two DOS file systems. One, known as the FAT (File Allocation Table) file system from the name of its key data structure, is the logical structure that DOS uses for media such as floppy disks and hard drives. The FAT is probably the world's best-known DOS internal data structure, having entered popular culture through Peter Norton's book *Inside the IBM PC*. Every book on non-BIOS programming discusses the various FAT structures as they are needed for disk services.

The other file system introduced in DOS 3.1 is known as the MS-DOS network redirector. Whereas most DOS programming interfaces consist of INT 21h or INT 2Fh functions that a program calls, the network redirector is instead a set of functions that MS-DOS itself calls. For example, when performing a file open operation, DOS issues an INT 21h with AX = 1116h. Any program can intercept INT 21h, AX = 1116h and thereby make use of a network redirector. When DOS tries to open a file, it calls a handler in the program. The program can handle the file open call itself, for example by sending a message requesting the file open over a network to a file server. Another way to do this with NetWare versions prior to 4.0 is to hook INT 21h directly and watch for all file-related calls. However, as we'll see, there are some advantages to using the network redirector.

Despite its name, the network redirector is a set of code in MS-DOS that DOS uses for mapping a DOS directory (or drive) onto a non-FAT system, such as network file servers and CD-ROM devices. Drives created with the network redirector do not require FATs or Disk Parameter Blocks. While networks are a predictably important part of the DOS file system, and one that discusses a lot of DOS internals in some detail, the network redirector is somewhat misnamed. It is not just for networks anymore. The network redirector is a mechanism that allows a somewhat primitive one for creating installable file systems.

All drives, whether FAT-based or non-FAT, have entries in a key DOS data structure called the Current Directory Structure, or CDS. An important exception to this statement is Novell NetWare, which prior to version 4.0 bypasses the CDS. Many programs, as this chapter mentions, manipulate the CDS in some way.

The CDS, together with many other DOS structures we discuss in this chapter, is shared by all programs. Since DOS is normally thought of as a single-tasking operating system, having one global structure doesn't seem like a problem. However, as DOS is increasingly called upon to run multi-tasking software such as Windows, the assumption that only one program is using the CDS at a time becomes more and more inaccurate. Almost all DOS internal structures are global and non-reen-

real-mode programs seriously restricting DOS's ability to perform true multitasking. That's one reason why multitasking extensions of DOS such as General Software's Embedded DOS, avoid using such structures (see Steve Isaacs, "32DOS Meets Real Time," *Embedded System Programming*, February 1992). Does this mean the Windows multiplex interface data structure described in Chapter 4 that Windows Enhanced mode uses instances of to create the illusion of multiple CDSs (see Figure 3-9, Clark, it would have been better if DOS supplied multiple CDSs, but an enhanced CDS is the next best thing.

In this chapter we'll read about DOS drives, directories, and files, and as in most such discussions we'll begin with the physical media and work our way to the directory structure seen by a typical DOS user. However, this chapter takes a somewhat different slant from most discussions of the DOS file system. Instead of showing how DOS applies a logical ordering to physical media, I'll show how to apply this same logical ordering to things other than hard drives and floppy disks. You'll see that in fact DOS's drive-oriented services now generalize the DOS notion of a drive as not just for physical media or even RAM disks anymore.

Also we'll see several additional layers of complexity to the DOS file system. First, as with any modern operating system, DOS is now built around disk caches. Disk caches such as SmartDrive introduce another level between the file system and the physical device. And, of course, the entire FAT file system doesn't rest directly upon the physical media. Instead, it goes through block device drivers (see Chapter 7). So, we'll see how DOS supports Drive Parameter Blocks (DPBs), such as the ability to read a given sector (number), the block device driver will implement it (however it sees fit). And don't forget disk compression software, such as Stacker and Microsoft DoubleSpace (DOS 6.0). We discuss Stacker and DoubleSpace later in this chapter.

This chapter contains many functions and sample programs, giving it more of a cookbook approach than the rest of this book. The chapter's prize for assistance is PHANTOMC, a complete replacement for DOS's default block device driver for reading a new drive. Readers of the first edition of *Undocumented DOS* should note that we've completely rewritten the Phantom in C instead of assembly language. And it's now a full-blown XMS RAM disk rather than a "proof of concept" toy. Other code in this chapter includes routines to:

- Detect DoubleSpace, Stacker drives, and RAM disks
- Get the compression ratio for a DoubleSpace drive
- Free up orphaned file handles
- Turn a cluster number into a file name or vice versa
- Derive a filename from a file handle
- Increase the number of process file handles
- Decode the FILES= and BUFFERS= values
- Set or turn off drive letters
- Walk the 12-bit and 16-bit File Allocation Table
- Walk the Current Directory Structure
- Walk the System File Table
- Get the true (canonical) name of a file
- List all the open files for any given process

We'll see how to do these operations in a logical rather than the physical aspects of the DOS file system. But first, let's take a quick overview of the file system, followed by a look at its physical aspects.

A Quick Overview of the System

To set the stage for a detailed discussion of the DOS file system, we need to trace the significant actions that take place when DOS services a function to read from or write to a file. One good way to examine these services in close is the COPY command, which reads the contents of one file and writes it to another.

One of our major tools for delving into the internal workings of DOS is INTRSPY, and it is program is what we use to see what happens inside the COPY command. Listing 8-1 shows the INTRSPY script we prepared. Just for debugging purposes of earlier versions of COMMAND.COM and the DOS kernel itself. This script includes such intermediary interfaces as INT 2Eh, 2Fh, INT 21h, XMS-12h, and the ROM BIOS INT 13h. With INTRSPY 2.0, we can even trace right on into the device driver Init, Interrupt and Strategy routines w/ DISKSCR includes DDSCR from Chapter 5. Listing 5-3.

Incidentally, while we are on that INT 13h is the ROM BIOS disk interrupt, it's important to note that MS-DOS hooks INT 13h instead of the BIOS, so you can see this by running INTCHAIN 13/0/0/0/0 (see Chapter 6).

For a more complicated example, see Chapter 9, which uses INTRSPY to examine in detail the process of formatting a floppy disk.

Listing 8-1: DISK.SCR

```
; DISK.SCR
; usage: cmdspy compile disk [drive] [command]
; example: cmdspy compile disk c:  command /c copy foo bar bar.foo > disk.log

; DOS 4+/Compaq DOS 3.31+ >32M partition
structure big_fields
    sector (dword,hex)
    num (word,hex)
    addr (dword,ptr)

intercept 21h
    function 32h
        on_entry output "2132: Get DPB drive " dl
        on_exit  output "2132: done"
    function 3Ch
        on_entry output "213C: Create File: " (ds dx->byte,asciiz,64)
        on_exit  output "213C: done, file is " ax
    function 6Ch
        on_entry output  216C  Ext Open/Create    (ds si->byte,asciiz,64)
            output "AX=" ax " BX=" bx " CX=" cx " DX=" dx
        on_exit  output "216C: done, "
            if (cflag==1) sameline "Error " ax
            if (cflag==0) sameline "file is " ax
            if (cx==1) sameline ", opened"
            if (cx==2) sameline ", created"
            if (cx==3) sameline ", replaced"
    function 3Dh
        on_entry output "213D: Open File: " (ds:dx->byte,asciiz,64)
        on_exit  output  213D: done, file is " ax
    function 3Eh
        on_entry output "213E: Close File " bx
        on_exit  output "213E: done: File " bx
    function 3Fh
        on_entry output  213F  Read File   BX
        on_exit  output "213F: done: File " bx
    function 40h
        on_entry output  2140: Write File " bx (ds dx->byte,asciiz,cx)
        on_exit  output  2140  done: File " bx
    function 44h
        subfunction 00h
            on_entry output  214400  IOCTL drive   bl   Attribs "
            on_exit  sameline dx
        subfunction 09h
            on_entry output  214409  IOCTL drive   bl " Remote? "
        subfunction 0Dh
            on_entry output "21440D: IOCTL drive " bl
                if (cl == 40h) sameline " [40: Set Device Parameters]"
                if (cl == 41h) sameline " [41: Write Track]"
```

```
            if (cl == 42h) sameline " [42: Format and Verify Track]"
            if (cl    60h) sameline "  [60: Get Device Parameters]"
            if (cl == 61h) sameline " [61: Read Track]"
        subfunction 0Fh
            on_entry output "21440F  IOCTL Set Logical Drive " bl
            on_exit if (cflag == 0) sameline " => " al

intercept 25h
    on_entry
        output "25: Abs Disk Read drv " al ", at sectr "
        if (cx == OFFFFh)
            sameline (ds:bx->big.sector) ", " (ds:bx->big.num) " sctrs"
        if (cx != OFFFFh) sameline dx ", " cx " sctrs"
    on_exit if (cflag==1) sameline " [fail]"

intercept 26h
    on_entry
        output "26. Abs Disk Write drv   al ", at sectr "
        if (cx == OFFFFh)
            sameline (ds:bx->big.sector) ", " (ds:bx->big.num) " sctrs"
        if (cx != OFFFFh) sameline dx ", " cx " sctrs"
    on_exit if (cflag==1) sameline " [fail]"

intercept 13h
    function 0 on_entry output "1300. Recalibrate drive " dl
    function 1 on_exit output "1301: Disk system status " al
    function 2
        on_entry
            output  1302: Read " al " sctrs: drv " dl ", head " dh
                , sctr " cl ", trk " ch " to " es  :" bx
        on_exit if (cflag==1) sameline " - FAILED (" ah ")"
    function 3
        on_entry
            output  1303  Write " al   sctrs: drv   dl ", head  dh
                , sctr   cl ", trk " ch " from " es     bx
        on_exit if (cflag =1) sameline " - FAILED (" ah ")"
    function 4
        on_entry
            output  1304  Verify " al " sctrs: drv " dl ", head " dh
                , sctr  cl ", trk   ch
        on_exit if (cflag==1) sameline   - FAILED (  ah  )"
    function 5
        on_entry
            output  1305  Format   al   sctrs  drv   dl  , head " dh
                , sctr   cl ", trk   ch
        on exit if (cflag==1) sameline " - FAILED (  ah  )
    function 8 on_entry output "1308: Get drive params for   dl
    function 0ch on entry output  1300  Seek cyl   ch   drv   dl " head " dh
    function 0dh on entry output  1300  Alternate reset drive " dl
    function 10h on entry output  1310  Test drive   dl
    function 15h on entry output  1315  Get type drv   dl
    function 16h on_entry output  1316  Get media change drv " dl
    function 17h on entry output  1317  Set type drv   dl "    al
    function 18h on_entry output  1318  Set media type drv   dl

include  dd scr 21 22  3 24  5 26 27 28  9   , DD SCR does RUN, REPORT
```

This INTRSPY script requires a command line with a drive letter and a DOS command. For example:

```
C:\UNDOC2\CHAP8>intrspy -R20480
E:\UNDOC2\CHAP8>cmdspy compile disk c  command /c copy foo.bar bar.foo
```

In this example, FOO.BAR is a text file containing only the line "this is foo.bar". Figure 8-1 shows part of the INTRSPY output when copying FOO.BAR to BAR.FOO.

Figure 8-1: INTRSPY Results for a DOS COPY

```
216C: Ext Open/Create: FOO.BAR
AX=6C00 BX=0040 CX=0000 DX=0101
01 - media check
04 - input
1302: Read 09 sctrs  drv 80, head 08, sctr 08, trk 03 to 1705:0000
04 - input
1302: Read 03 sctrs  drv 80, head 0A, sctr 40, trk 36 to 1003:0000
1302: Read 01 sctrs, drv 80, head 08, sctr 40, trk 37 to 1063:0000
04 - input
04 - input
04 - input
216C: done, file is 0005, opened
214400  IOCTL drive 05 Attribs 0042
213E: Close File 0005
213E: done  File 0005
01 - media check
01 - media check
216C: Ext Open/Create: FOO.BAR
AX=6C00 BX=0040 CX=0000 DX=0101
01 - media check
216C  done, file is 0005, opened
214400  IOCTL drive 05 Attribs 0042
213F  Read File 0005
04 - input
1302  Read 09 sctrs, drv 80, head 01, sctr 07, trk 04 to 1685:0000
1302  Read 01 sctrs, drv 80, head 02, sctr 42, trk 28 to 1003:0000
213F  done, File 0005
213E, Close File 0005
213E  done  File 0005
216C: Ext Open/Create: BAR.FOO
AX=6C00 BX=0040 CX=0000 DX=0101
01 - media check
216C: done, file is 0005, opened
214400: IOCTL drive 05 Attribs 0042
213E  Close File 0005
213E  done  File 0005
01 - media check
216C: Ext Open/Create  BAR FOO
AX=6C00 BX=0021 CX=0000 DX=0112
01 - media check
04 - input
1302  Read 09 sctrs  drv 80, head 02, sctr 08, trk 04 to 1705:0000
08 - output
1303  Write 01 sctrs  drv 80, head 06, sctr 0A, trk 03 from 1223:0000
1303  Write 01 sctrs, drv 80, head 02, sctr 09, trk 04 from 101D:361C
08 - output
1303  Write 01 sctrs  drv 80, head 08, sctr 09, trk 05 from 101D:361C
08 - output
216C: done, file is 0005, replaced
214400  IOCTL drive 05 Attribs 0042
01 - media check
2140: Write File 0005this is foo.bar

2140: done: File 0005
214400  IOCTL drive 05 Attribs 0002
213E: Close File 0005
01 - media check
08 - output
08  output
```

```
08   output
08 - output
03 - ioctl input
1303  Write 01 sctrs  drv 80, head 0B, sctr 06, trk 46 from 1000:0000
1303  Write 03 sctrs  drv 80, head 0A, sctr 4D, trk 36 from 1008:0008
1303  Write 01 sctrs  drv 80, head 08, sctr 48, trk 37 from 1068:0008
1303  Write 05 sctrs  drv 80, head 02, sctr 09, trk 04 from 1765:0000
1303  Write 05 sctrs: drv 80, head 08, sctr 09, trk 05 from 1765:0000
213E  done, File 0005
2140: Write File 0001        1
04 - input
1302  Read 01 sctrs  drv 80, head 0B, sctr 05, trk 46 to 1003:0000
2140  done: File 0001
2140  Write File 0001 file(s) copied

2140, done: File 0001
```

COPY uses the initial open function 6Ch for opening and creating files instead of the older function 3Dh. When called to open FOO.BAR this function calls block device driver function 4, Read, which accesses the BIOS INT 13h to read the root directory from the C: drive. COPY then calls XOR AX,AX function 43h to get the file's attributes and closes the file.

Next, again, shows COPY opening the same file again. This time COPY reads the file's entire contents into a buffer whose closing, in the file. Again, the command interpreter COMMAND.COM is left to intervene immediately after performing the open. The program then calls function 31h to do the actual writing to disk. Function 31h tells DOS to perform the actual work, though not directly, of course. Function 31h in turn calls the block device driver's Interrupt and Strategy routines, using device header information. Finally, the device driver function calls the BIOS. For more information on how block level devices fit into the DOS file system, see Robert S. Lai, *Writing MS-DOS Device Drivers*, second edition, Chapters 7 and 8.

When COPY is ready to write the data, the next step is to invoke function 6Ch by attempting to open the file it is creating. This time it determines if the destination file, BAR.FOO, exists. This call succeeds, indicating that the file does. Next, DOS reads in directory information because that information is not already in DOS buffers. Some previous disk read is required. The values function 6Ch returns indicate that BAR.FOO is open, meaning that the file already exists from a previous test.

After opening BAR.FOO for write access, COPY closes the file then immediately reopens it for writing with function 3Dh. COPY could just as easily truncate the file. This time, it uses several BIOS disk writes as the COPY function overwrites the previous copy of BAR.FOO. It updates both FATs, then modifies the directory entry for the file to reflect a length of zero bytes together with a new date/time stamp.

Next, COPY writes the data it was earlier read in from FOO.BAR, but as clearly seen in figure 8-1, not as a single write operation. Write function 40h "2140 done" appears immediately after control to the operating system returns to the device driver for the BIOS. Another IOCTL attribute check command indicates that write has taken place. The attribute has changed from 0042h to 0002h. A Write function 40h moved the data from COMMAND.COM's buffer area to the DOS buffers, but the data was not yet made to go to the disk. Clearly, buffers play a crucial role in DOS file I/O, see BUFFERS in Listing 8-8.

When function 31h begins the file's creation, DOS does all of the deferred writing. It allocates disk space, updates both FATs, writes the actual data with device driver function 8, Write, and finally updates the directory entry for BAR.FOO.

The final action shown in our trace are calls to the Write function to Handle 1, stdout, to create the "1 file(s) copied" display.

All that's left to explain is the "Abort" as noted earlier, even this inside view of the COPY command was quite superficial. We didn't get into what happens with disk compression such as Stacker or DoubleSpace, or what happens if you're using a disk cache such as SmartDrive. Still, the ENTRSPY

results provide a useful overview of the typical sequence of events involved in actual disk I/O. Now let's look at the physical aspects of disk storage.

The DOS File System

The starting point for the FAT file system is generally the physical disk and the drive mechanism itself. These marvels of mechanical precision convert a stream of information represented as a sequence of bits into a corresponding sequence of magnetic flux reversals that are placed on the surface of the disk.

Someone could write entire books on the methods by which this is done, but you and I and disk drive designers would read them. As programmers, we're more interested in how program-oriented descriptions of data are translated into the terms that actual disk hardware requires.

These translations occur on several levels. Programs organize data into a stream of bytes and store these streams on files, which are later read back as streams. DOS translates requests to files into references to logical drive locations called *clusters*. The cluster size is part of the physical disk structure, but instead of working with that, the FAT code in DOS converts the cluster number into a logical sector number (LSN) for transmission to a block device driver. If the device driver supports a physical disk, it translates the LSN into the more traditional values of *track*, *head*, and *sector* for transmission to the specific device. The BIOS and the drive controller then translate these values into the sequences of pulses that select the addressed drive, position the actuator to the desired cylinder of tracks, select the specified head, and begin reading from it when the correct sector is located. (For a detailed examination of the BIOS and drive controller, see Frank van Gilluwe's *The Undocumented PC*.)

Surfaces, Tracks, and Sectors

One starting point for gaining an understanding of the DOS file system is the surface of the magnetic medium used, as exemplified by the familiar floppy disk. Hard disk operates in much the same way, but with much greater precision.

In the earliest days of MS-DOS, the typical IBM PC came equipped with a single-head, single-sided disk drive rated at a storage capacity of 160K per disk. The head made contact with the right side of the diskette when a door was closed. The drive motor turned the platter, and the position of the head against the lower surface of the diskette was a key parameter. A spring pressure pad held the diskette against the upper surface.

On the single-sided surface, the head actuator could latch onto any of 40 concentric tracks. The head actuator mechanism was moved to one of these positions to align the head accurately over the desired track. The track nearest the outer edge of the disk was designated as track 00, the one nearest the hub hole, as track 39.

A serial index hole near the edge built into the diskette provided a reference point to determine disk rotation. A sensor in the disk drive generated an index pulse each time this hole passed over it, and since the disk rotated at a constant speed of 300 RPM (200 milliseconds per revolution), the associated control circuitry could locate offsets around the track in which to store data. These drives contained eight sectors per track, each sector with room for 512 bytes of storage, between sector address markers. Several special identification codes helped the controller verify that it was at the right place on the drive. Thus, each track contained 8*512 bytes of data, or 4,096 bytes, and the 40 tracks held a total of 163,840 bytes, or 160K.

Before long, the single-sided drive was supplanted by a two-headed model that could read and write on both surfaces, immediately doubling the storage capacity to 320K per disk. MS-DOS 2.0 added support for an extra sector on the format, bringing the storage capacity up to 360K. Later, similar-sized 1.2MB drives, rotating at 360 RPM and reading 80 rather than 40 tracks, came on the scene. But the basic principles held true for these drives as well as for 3.5-inch units that today's boxes have to offer.

DOS leaves the drive itself dictates storage locations in terms of which head is used, which track is over the read/write heads, which sector of that track is positioned over the head, and which sector of that track is read or written.

Humans, however, have difficulty remembering a large collection of numeric values. Instead, we like to name things. It seems much simpler to remember that this text is stored in a file named CHAPS.DOC, rather than it is stored starting at sector 14 of cylinder 93, head 5, of drive 3. That's part of what the DOS file system is all about. It permits us to deal with our programs and data as named files. It turns over to the computer the job of translating these names into the sequences of numeric data that the hardware requires. Since computers excel at dealing with numeric information, it is just another example of letting the computer do what it does best, so that humans can do what they do best.

Another aspect of the DOS file system extends this type of mapping to non-storage devices. RAM disks, for example, map a file's directory entry into fast, volatile memory. DOS's simple I/O redirection facility allows us to treat the screen and keyboard ports (CON), serial ports (COM1), and parallel ports (LPT1) as files. Drives created with the DOS network redirector can map a file system structure's packets sent over the network to another machine, possibly running a completely different file system. The file system, in other words, not only simplifies access to hardware, but also provides unified access to otherwise disparate devices.

In order to let us deal with stored programs and data as named files, rather than forcing us to use physical head, track, sector addresses for every read or write action, the DOS file system maps these physical addresses into logical sector numbers and groups blocks of adjacent sectors into clusters for allocation to named files.

We'll cover these processes in detail shortly. But first, let's look at some special records that are not part of the file system, but without which the file system would not exist. These are the partition record, which can treat a single physical drive as multiple logical drives, and the boot record, often called the boot sector, since under DOS this record occupies a single sector, which controls the boot process each time you power up your system.

Partition and Boot Records

The partition record came into use soon after hard disks became popular. The original purpose was to allow multiple operating systems, such as MS-DOS and UNIX, to exist on the same system and not interfere with each other. However, the capability quickly provided a way to deal with the 32-megabyte volume limit for hard disk drives that existed prior to MS-DOS 3.31 by allowing multiple 32-MB (or smaller) drives to be set up on a single physical device. The presence of hard disk partitions shows that a hard disk is just a logical construct, rather than a physical reality. Hard disk C: may be just one subsection of the physical hard disk.

The boot record first dealt with early versions of the first disk operating systems. Its purpose is to control system operation at that brief period of time when the full operating system has not yet been read into memory, so that a record stored in a fixed location on the disk can be read from the disk.

MS-DOS FDISK creates a partition record in the first sector of the first track under the first head (Drive 80h, H=0, T=0, S=1). The IBM DOS utility modifies this record, sometimes also called the Master Boot Record (MBR), to establish the physical limits on the logical drives and thus permits multiple logical drives to exist on a single physical drive. When you power up the system, the ROM BIOS reads the MBR into memory and transfers control to it. The code in this record, in turn, reads in the boot record for the currently specified bootable partition, then jumps to the code in that boot record.

Since the partition record is not inside any logical drive, and since DOS deals only with logical drives, the usual case is that each physical drive has only one logical drive, which occupies all available space. Normally, you cannot access this record. You can, however, read it with the BIOS disk read function (INT 13h, AH=02), as the following DEBUG script shows:

```
a
MOV AX,0201      ; AH=ReadSec, AL=number to read (1)
MOV BX,1000      ; buffer at ES 1000h, ES set by loader
MOV CX,0001      ; CH=cyl (0), CL=sector (1)
MOV DX,0080      ; DH=head (0), DL=drive (C:)
INT 13           ; call BIOS disk function
JMP 0100         ; provides place to set breakpoint

g 10e
d 1000 l200
q
```

The blank line after INT 0100 is essential; it signals DEBUG that the A assembly command is complete. To use this script for DEBUG, type it into a file, RPART.SCR, then type

```
DEBUG < RPART.SCR > PART.CAP
```

This creates a file named PART.CAP containing a hex dump of your C: drive's partition table. To read from your D: drive, you can change the value set into DX from 0080h to 0081. Figure 8-2 shows an edited version of sample results from this script; we added spaces to create four byte columns.

Figure 8-2: A Partition Record

```
0000: FA 2B C0 8E  D0 BE C0 8E  D8 B8 00 7C  8B E0 FB 88    *+.        |
0010: F0 8F 00 7E  FC B9 00 01  F3 A5 E9 00  02 B9 10 00
0020  BB 36 85 7E  F6 04 80 75  08 83 EE 10  E2 F6 EB 37    6.~  u       7
0030. 90 8F 8E 07  57 B9 08 00  F3 A5 5E BB  00 7C 8B 14      W    .^
0040- 8B 4C 02 8D  05 00 B8 01  02 CD 13 73  09 28 C0 CD    L         s (
0050: 13 4D 74 19  E8 F0 BE FE  7D AD 3D 55  AA 75 14 8E    Mt      }  U u
0060  BE 07 EA 00  7C 00 00 BB  36 87 7E EB  0A 8B 36 B9       |   6 ~   6
0070  7E E8 04 8B  36 8B 7E AC  0A C0 74 FE  8B 07 D0 B4      6   ~   t
0080: 0E C0 10 EB  F2 EE 7F 80  7E A7 7E C8  7E 00 0A 69              ~ ~  i
0090  6E 76 61 6C  69 64 20 50  61 72 74 69  74 69 6F 6E    nvalid Partition
00A0- 20 54 61 62  6C 65 00 00  0A 45 72 72  6F 72 20 4C     Table   Error L
00B0  6F 61 64 69  6E 67 20 4F  70 65 72 61  74 69 6E 67    oading Operating
00C0. 20 53 79 73  74 65 6D 00  00 0A 40 69  73 73 69 6E     System   Missin
00D0  67 20 4F 70  65 72 61 74  69 6E 67 20  53 79 73 74    g Operating Syst
00E0  65 6D 00 00  00 00 00 00  00 00 00 00  00 00 00 00    em
00F0. 00 00 00 00  00 00 00 00  00 00 00 00  AA 55 00 00                  U
0100  00 00 00 00  00 00 00 00  00 00 00 00  00 00 00 00
;       lines omitted, all zeroes
0180: 00 00 00 00  00 00 00 00  00 00 00 00  00 00 80 01
01C0: 01 00 06 08  DF FE 11 00  00 00 56 63  02 00 00 00                Vc
01D0  00 00 00 00  00 00 00 00  00 00 00 00  00 00 00 00
01E0  00 00 00 00  00 00 00 00  00 00 00 00  00 00 00 00                  .
01F0  00 00 00 00  00 00 00 00  00 00 00 00  00 00 55 AA                  .U.
```

The first 254 bytes up to and including the signature AA55 at offset 01FEh in the record is the code used for a second boot to determine which of the 4 possible partitions to use for the startup process. The remaining bytes are except for the final signature AA at offset 01Fh for a table of sixteen 16-byte entries, each of which describes the limits of a logical partition. In Figure 8-2 one such entry starts with the byte 80h at offset 1BEh.

Microsoft does not document the layout of each entry; see the PARTITION_RECORD structure in the *MS-DOS Programmer's Reference*. This is the arrangement for each of the 16 entries:

```
struct PartEntry {
  char BootableFlag,        /* 80h = bootable partition, else 00h */
  char StartHead;           /* starting head number */
  char StartSector,         /* Bits 0-5 are start sector, 6-7 cy  */
  char StartCyl,            /* Low 8 bits of start cyl, 8-9 to prev */
  char SystemID,            /* Encodes file system type, see below */
  char EndHead;             /* ending head number */
```

```
    char EndSector,             /* ending sector and hi bits of cyl */
    char EndCyl,                /* low bits of ending cyl number */
    unsigned long AbsBegin,     /* nbr, relative to disk, of first sec */
    unsigned long SectCount,    /* total number of sectors in partition */
    };
```

The System ID byte can hold any value since most MS-DOS operating systems also use this partition table. As of version 5.0, MS-DOS recognizes the following values:

00h = Unknown type or unused entry
01h = MS-DOS, 12-bit FAT
04h = MS-DOS, 16-bit FAT, partition < 32 MB
05h = MS-DOS, extended partition
06h = MS-DOS, 16-bit FAT, partition >= 32 MB

Ralf Brown's Interrupt List provides values for other operating systems. Chapter 16 of his *DOS Internals* book also discusses partitions.

Each of the sixteen partition entries corresponds to a partition. In Figure 8-2, only one of the sixteen partition entries is not zero because this drive was partitioned as a single 76-megabyte logical volume. The value 80h at offset 1BEh indicates that this partition is bootable. The value at 1BFh says that the partition begins on head 1, that at 1C0h specifies sector 1, and that at 1C1h—together with the high two bits of 1C0h—indicates cylinder 0. The 80h at offset 1C2h shows that this is a DOS volume using 16-bit FAT entries. Since it is larger than 32 megabytes, the next three bytes specify the ending head, sector, and cylinder. The value 00000801h starting at offset 1C6h means that the partition begins on the 2049th sector from the start of the physical disk, and the 4-byte value 0002e356h at offset 1CAh is the total sector count for the volume.

Partitions are created with the FDISK utility. Commented C source code for an FDISK utility, along with code for FORMAT, CHKDSK, SYS, DISKCOPY, and other programs, is included with the excellent Turbo DOS kit available from General Software, Redmond, WA.

The Boot Record and BIOS Parameter Block (BPB)

The boot record, which Microsoft calls *the track 0 sector* in the MS-DOS 5.0 documentation, occupies the first sector of each DOS bootable partition. FDISK will not set you up with more than one DOS bootable partition, so we'll assume a physical drive. The code at the partition record reads the boot record into memory. Then it examines the boot record to see if it's a DOS disk. Let's use the DEBUG.EXE command to load the boot record, the first sector of the partition, into memory. For instance, L 400 2 0 1 at the DEBUG's prompt reads one sector (1) starting with the first sector (0) on drive C (2) to offset 1000:400. DEBUG, unlike most DOS utilities, numbers sectors with zero elsewhere; the first sector is sector 1. Figure 8-3 shows how to view DOS boot records with DEBUG.

Figure 8-3. Using DEBUG to View DOS Boot Records

```
C:\UNDOC2\CHAP8>debug
-L 100 2 0 1
-d 100 200
81E2:0100  EB 00 90 53 54 41 43 48-45 52 20 00 02 10 01 00   ...STACKER .....
81E2:0110  02 00 02 00 00 F8 66 00-3F 00 0F 00 00 00 00 00   ......f.?.......
81E2:0120  4B 25 03 00 00 14 00 00-00 01 09 00 20 47 32 00   K%.......... G2.
81E2:0130  00 0C 00 ED 00 CD 00 00-00 00 00 00 00 00 00 00   ................
81E2:0140  00 53 54 41 43 56 4F 4C-2D 30 30 30 43 7D 00 AB   .STACVOL-000C}..
;;      etc
;; that's a Stacker drive; let's look at its host, a normal DOS drive
-L 100 3 0 1
-d 100 200
81E2:0100  EB 3C 90 4D 53 44 4F 53-35 2E 30 00 02 04 01 00   .<.MSDOS5.0.....
81E2:0110  02 00 02 00 00 F8 7A 00-11 00 0C 00 11 00 00 00   ......z.........
81E2:0120  9F E7 01 00 80 00 29 E7-11 51 1B 4E 4F 20 4E 41   ......)..Q.NO NA
```

```
81E2:0130  4D 45 20 20 20 20 46 41-54 31 36 20 20 20 FA 33   ME    FAT16   3
81E2:0140  C0 8E D0 BC 00 7C 16 07-BB 78 00 36 C5 37 1E 56   .....|...x.6.7.V
;...
-u 0100 102
81E2:0100 EB3C          JMP 013E      ; bsJump
81E2:0102 90            NOP
;...
0103h       db  'MSDOS5.0'            ; bsOemName
;;; beginning of BPB
010Bh       dw  0200h                 ; bsBytesPerSec
010Dh       db  04h                   ; bsSecPerClust
010Eh       dw  0001h                 ; bsResSectors
0110h       db  02h                   ; bsFATs
0111h       dw  0200h                 ; bsRootDirEnts
0113h       dw  0000h                 ; bsSectors (0, see bsHugeSectors)
0115h       db  F8h                   ; bsMedia (F8h = hard disk)
0116h       dw  007Ah                 ; bsFATsecs
0118h       dw  0011h                 ; bsSecPerTrack
011Ah       dw  000Ch                 ; bsHeads
011Ch       dd  00000001h             ; bsHiddenSecs
0120h       dd  0001E79Fh             ; bsHugeSectors
;;; end of BPB
0124h       db  80h                   ; bsDriveNumber (80h = first hard disk)
0125h       db  00h                   ; bsReserved1 (used during boot)
0126h       db  29h                   ; bsBootSignature  (29h = extended BPB)
;;; start of extended BPB (see Media ID)
0127h       dd  185111E7h             ; bsVolumeID (midSerialNum)
012Bh       db  'NO NAME    '         ; bsVolumeLabel (midVolLabel)
0136h       db  'FAT16   '            ; bsFileSysType (midFileSysType)
;;; end of extended BPB
```

The first three bytes of Figure 8.3 JMP instruction, which tells you an unassemble of course that first verifies that the disk is indeed a system disk. Then the code reads in the IO.SYS file, which then takes over the startup process.

Immediately after the JMP instruction is a set of data items that Microsoft documented in the DOS programmer's reference (see BOOT.SEC.IOR). This set includes a structure called the BIOS Parameter Block (BPB), documented in the device driver chapter of the DOS programmer's reference.

As Figure 8.3 shows, the BPB contains information about a storage medium, such as the bytes per sector, sectors per cluster, number of FATs and root directory entries, and so on. As you'll see later, however, DOS may overwrite some of the values in a BPB, so the BPB that IO.SYS maintains in memory doesn't necessarily match a BPB on a disk. For example, the number of FATs for floppy and hard disks is 2, no matter what the disk's own BPB contains. (For further discussion, see Chapter 15, *DOS Internals*, Chapter 10.)

Note the presence of what is called an extended BPB. You can retrieve this data with the generic IOCTL Get Media ID call (INT 21h, AX=4400h, CX=0866h), which is equivalent and generally preferable to the undocumented INT 21h, AH=69h. The inclusion of a volume label in the extended BPB means that a volume label might be stored both as a special attribute in the root directory. In MS-DOS 4.0 and higher, you can set an Ignore volume label switch with the Get/Set Media ID calls. Note, however, that this switch works for media that in fact does have an extended BPB. For disks formatted under MS-DOS 3.0, for example, Get Media ID returns an error code, so you then must retrieve and set the volume label using an old method that requires an FCB.

DoubleSpace has further extended the BPB to a structure called the MDDBPB (the MDD stands for MagicDisk; see the DoubleSpace discussion later in this chapter).

Logical Sector Numbers and the Cluster Concept

The first step toward simplifying the head/track/sector number sequence was to recognize that there was a more efficient way to manage space, by referring to every sector on a disk unit with a single number rather than with three.

DOS assigns these numbers to the sectors in logical sequence. That is, the first sector (S=1) of the first logical track (T=00) under the first logical head (H=0), which in the IBM hardware oriented scheme, takes into account the partition offset, (head 1, track 0, sector 1) would be (H=1, T=00, S=1) becomes Logical Sector Number (LSN) 000. Peek-level code in the PC start numbering physical sectors from 1, not 0. The calculations necessary for converting the LSN work with values that are relative to the start of the logical disk unit (usually the partition) rather than to the physical drive. The rest of the way around that first track on the same surface, the numbers follow in sequence.

Then, however, the LSN jumps to the other surface of the disk. For a 360K diskette, with no partition record and nine sectors per track on both sides, LSN 10 would be (H=1, T=00, S=1). After all sectors on track 0 of the second side are accounted for, the numbering returns (H=0, T=01, S=1) for track 1 of the first side, which becomes LSN 19.

I won't list the equations for the exact translation process either, but the essential point is that you can always convert a head/track/sector reference into a unique LSN and you know how many sectors are on each track, how many tracks the disk provides, and where the logical volume begins with respect to the physical drive. You can reconstruct the reverse translation.

Working around DOS partitions, both translations can be difficult because no clean way exists with which DOS tools can find the start location of the partition other than by reading the partition table and using the data found in the appropriate entry there. The problem with extended partitions, described in which DOS applies to the extended partitions with which you are dealing. For more information on extended DOS partitions, see Chapter 16 of Scott Chappell's *DOS Internals*.

Today's high-capacity storage units, which may contain hundreds of thousands of 512-byte sectors, the LSN is not a granularity that DOS typically needs to allocate disk space and to access files. DOS uses the concept of clusters. DOS inherited this idea from the older CP/M operating system, although CP/M uses the term *extent*. A cluster is simply a group of adjacent sectors that are always associated with each other. Doubling the number of sectors per cluster cuts in half the number of clusters on the disk, but it gives a sizable speed boost. This solves several problems and creates some new ones.

Allocating storage by multiple sectors (clusters) greatly reduces DOS overhead in allocating and freeing disk space, since DOS performs these functions a fraction as frequently as it would if it allocated space one sector at a time. Multiple-sector clusters also serve to speed up disk access by reducing (though by no means eliminating) the chance that sectors will be scattered all over the drive. Logical sectors in two clusters in the same track are adjacent to each other, and most within each cluster all the sectors are together. Smaller seek times result, so part of disk I/O delay disappears, and overall system performance improves.

On the other hand, the use of clusters means that when there is more than one sector per cluster, they are assigned to files in chunks of disk space, as opposed to one sector at a time. Even if the file is only a few bytes long, it will be allocated 512 bytes per sector and 8 sectors per cluster, then the minimum space allocated for a file is 4,096 bytes, even for a file whose size in a directory listing is one byte. Not exactly a problem for most users. The unused space is known as *cluster overhang*.

Software designed to operate on Solid State RAM disks such as Microsoft's RAMDRIVE.SYS use only one sector per cluster. Lower-density diskette formats use a cluster of only two sectors. 1.2 MB and higher-density diskettes use four sectors per cluster. Hard disks for the most part use either 4 sector or 8 sector clusters. Some optical drives use larger clusters as an alternative to larger sector sizes, to deal with gigabytes of space under older versions of DOS. DOS has a built-in limit of 128 sectors per cluster (in MS-DOS 5.0, some FCB handling breaks down under this condition, so in practice 64 sectors per cluster is tops).

One way that DoubleSpace compresses disks is by allocating a *fraction* of a set of sectors per cluster. Rather than converting from clusters to sectors via a fixed formula, DoubleSpace uses a lookup table called the MDFAT. We discuss DoubleSpace in greater detail later in this chapter.

To tell which clusters are in use and which are available for assignment, DOS uses the famous File Allocation Table (FAT) with one entry per cluster. The cluster structure is the backbone of the FAT file system. If a damaged area of data on the affected disk and may be lost

The File Allocation Table (FAT)

The FAT is always located near the front of each disk volume, generally immediately after the boot record. The FAT starts at what would normally be a cluster boundary at the first sector after the boot record. DOS normally maintains two copies of the FAT in case of hard disk errors or other logical errors. DOS tries successfully write both copies each time space is allocated or released, but only needs to read one of them. If DOS ignores an error reading the first copy of the FAT and successfully read the second copy. Microsoft uses Direct FAT access to Shared Access Disk BASIC (1979) this is where the name per FAT index and in fact FAT itself comes from. For some of the goals of FAT see Tim Paterson, "A Look Inside MS-DOS," *Byte*, June 1983.

The FAT contains a list of cluster numbers. That is, you use a cluster number as an index into the FAT. The value at FAT cluster number is either another cluster number or an end of file indicator. These cluster numbers indicate the actual order of disk files, directories, and free space.

Some may each element of the FAT may be a 16- or cluster number, but are not quick for smaller media. FAT is more convenient-sized 12-bit quantities.

For DOS 3 and higher, the top 4 bits of the highest cluster word of the Drive Parameter Block tell which FAT size is in use for a specific volume. DOS 4.0 added a bed to the extended BPB containing an 8-character file system type identifier, which can be "FAT12" or "FAT16", with the unused three bytes padded with space characters. See also "Extended BPB" in Figure 8.3. You can access this field with INT 21h AX=440Dh CX=0860h (Get Media ID).

Because of the FAT16 limit of 65,526 clusters, it is theoretically possible to have as big a FAT entry for media with 64 thousand clusters. However, the DOS kernel reserves 2 bad FAT entries when there is sufficient room, so the media's highest cluster number. Although the System ID field in the partition record identifies whether each partition uses a 12-bit or 16-bit FAT, DOS doesn't use this information. Because of this, sector overlapping might cause that happens to some removable media, but not to fixed-disk partitions, which still require FAT to be usable under DOS. So in practice, it is adequate to just check the top four bits of the highest cluster number (highest cluster >> 12) to determine the FAT size.

Even with the large-volume support in DOS 4.x and up, most the FAT entries size in DOS itself never exceeds 16 bits, despite occasional claims to the contrary. What does increase as the volume size grows is the cluster size, with the modifications noted earlier, and the maximum FAT. Hooks are available to permit creation of custom file systems using other FAT sizes; a third party vendor perhaps could write a FAT24 or FAT32 system, but DOS itself recognizes only the 12- and 16-bit sizes.

Each cell in the FAT, whether 12 or 16 bits long, corresponds to a single cluster of the drive's storage space. The first two locations, which would refer to cluster 0 and cluster 1, instead hold media information. The first byte of the FAT indicates the Media Code that describes removable media. These codes correlate with the drive's own type. The remaining 16 or 24 bits of the first two entries are normally set to 1's and remain unused. It appears that DOS may use cluster 1 as a temporary sector marker while building an allocation chain for a file, and it uses cluster 0 as a shorthand reference to the root directory for any drive when defining the directory entry for a subdirectory from the root.

Cluster 2 is the first one usable for data. Since both copies of the FAT and the volume's root directory area precede this space, DOS must calculate the LSN for cluster 2 from the values provided in the DPB. Note though that DOS is not consistent in performing this calculation; as a result, if a root directory does not contain some exact multiple of 16 entries, things become confused. DOS 5.0 rounds down when doing the calculation, while MS-DOS 6.x rounds up.

Once the LSN for cluster 2 is known, the LSN at which any cluster starts is determined by multiplying the cluster number minus 2 by the sectors per cluster, then adding the known LSN for cluster 2. That's how DOS translates cluster numbers taken from directory entries into the LSNs that block device drivers need. As noted earlier, the LSN for cluster 2 is calculated from values in the DPB. But we'll get ahead of ourselves. DPBs are explained shortly.

The value contained in each FAT element tells whether the corresponding cluster is in use or not, and if it is, the element gives essential information about the file that is using it. A zero indicates that the cluster is free and can be allocated. A value of 1 should never occur, although you can trap such a value on disk I/O requests or INT 24h errors or on single stepping through an INT 21h function and have a low enough setting for BUFFERS.

Two successive bytes contain FFF8h–FFFFh for 12-bit FATs or FFF8h–FFFFh for 16-bit FATs to indicate that the cluster is the last one in the file. FFF7h marks a bad cluster. FFF0h through FFF6h are reserved, meaning that they're not used and quite possibly never will be. Any other value value identifies the next cluster in the cluster having that value; next cluster = FAT[cluster].

Incidentally, because FFF0h is the highest cluster number, because 2 is the first valid cluster number, and because each file must contain at least one cluster, there can be at most FFF0h − 2 = FFEDh (65,517) files and directories per DOS volume. 65,517 is not a large number.

Listing 8-2 creates a utility program, FAT.C, which prints out the FAT chain for any drive and cluster number specified on the command line. For example, the following shows that the file starting at cluster 1470 on drive C: occupies 88 clusters distributed in nine different places on the disk:

```
C:\UNDOC2\CHAP8>fat c: 7470
7470-7486 (17)
7491 7492 (2)
7494-7502 (9)
7512-7514 (3)
7544-7545 (2)
7554-7556 (3)
7683-7715 (33)
7729-7746 (18)
7752

88 clusters in 9 groups
(10% fragmentation)
```

Run FAT, specifying a cluster number of 7470 on drive C:. You'll see how filenames are mapped to clusters in a few moments, see NAMEINI.C in Listing 8-5.

Listing 8-2: FAT.C

```
/*
FAT.C -- Given drive and cluster number, print FAT chain
Andrew Schulman, July 1993
*/

#include <stdlib.h>
#include <stdio.h>
#include <ctype.h>
#include <dos.h>
#include "diskstuf.h"

void fail(const char *s) { puts(s); exit(1); }
```

```
main(int argc, char *argv[])
{
    DPB far *dpb;
    WORD prev_cluster, cluster, num_clusters = 0, num_groups = 0,
    WORD start_cluster,
    int drive,

    if (argc < 3)
        fail("usage: fat [drive] [cluster]");
    drive = toupper(argv[1][0]) - 'A';
    cluster = atoi(argv[2]);            // decimal, not hex

    if (! (dpb = get_dpb(drive + 1)))  // see DISKSTUF.C (listing 8-6)
        fail("can't get DPB");
    start_cluster = cluster,
    // the following works because get_fat_entry() returns
    // 12-bit EOF in 16-bit form!
    #define EOF(cluster) ((cluster) >= 0xFFF0)  // end of file
    while ( ! EOF(cluster))
    {
        num_clusters++;
        prev_cluster = cluster;
        cluster = get_fat_entry(drive, dpb, cluster),
        #define CONTIGUOUS(x,y) ((x) == ((y) + 1))
        if (! CONTIGUOUS(cluster, prev_cluster))
        {
            int num_clust = prev_cluster + 1 - start_cluster,
            num_groups++,
            if (num_clust > 1)
                printf("  u-%u (%u)\n",
                    start_cluster, prev_cluster, num_clust),
            else    // only one cluster
                printf("%u\n", start_cluster);
            start_cluster = cluster,
        }
    }
    printf("\n%u clusters in %u groups\n", num_clusters, num_groups),
    if (num_clusters > 2 && num_groups > 1)
        printf("(%u%% fragmentation)\n", (num_groups * 100) / num_clusters),
    return 0;
}
```

FAT.C includes the header file DISKSTUF.H (listing 8-3) and uses the get_dpb() and get_fat_entry() functions from DISKSTUF.C (listing 8-4). We use DISKSTUF again later in this chapter. All the hard work in FAT.C is done by get_fat_entry(), although "hard work" is a relative statement when working with 16-bit FATs: all the difficulty is in handling 12-bit FATs. FAT.C depends on get_fat_entry() to return 12-bit EOF markers in 16-bit form. Because get_fat_entry() masks the difference between 12-bit and 16-bit FATs, FAT.C doesn't know or care what type of FAT it's dealing with.

Listing 8-3. DISKSTUF.H

```
/*
DISKSTUF.H -- Some functions and structures for low-level disk access
Andrew Schulman, July 1993
*/

#ifndef DISKSTUF_H
#define DISKSTUF_H

typedef unsigned char BYTE,
typedef unsigned short WORD,
typedef unsigned long DWORD;
```

```
typedef char *STRING,
extern void fail(const char *s);    // application must define
#pragma pack(1)
typedef struct {
    BYTE name[8], ext[3], attrib,
#ifdef OS2
    BYTE reserved[8],
    WORD ea_handle,     // OS/2 handle to extended attributes (EAs)
#else
    BYTE reserved[10];
#endif
    WORD time, date, cluster;
    DWORD size;
    } DIR_ENTRY,
#define VOLUME_ATTR      0x08
#define DIRECTORY_ATTR   0x10
#ifndef MK_FP
#define MK_FP(seg,ofs) \
    ((void far *)(((DWORD)(seg) << 16) | (ofs)))
#endif
typedef struct dpb {                    // Disk Parameter Block
    BYTE drive, unit;
    WORD bytes_per_sect;
    BYTE sectors_per_cluster;           // plus 1
    BYTE shift;                         // for sectors per cluster
    WORD boot_sectors,
    BYTE copies_fat,
    WORD max_root_dir, first_data_sector, highest_cluster,
    union {
        struct {
            BYTE sectors_per_fat,
            WORD first_dir_sector,  // root dir
            void far *device_driver,
            BYTE media_descriptor, access_flag;
            struct dpb far *next;
            DWORD reserved,
            } dos3,
        struct {
            WORD sectors_per_fat;       // WORD, not BYTE!
            WORD first_dir_sector,
            void far *device_driver,
            BYTE media_descriptor, access_flag,
            struct dpb far *next;
            DWORD reserved,
            } dos4,
        } vers,
    } DPB,
#pragma pack()

DPB far *get_dpb(int drive),
int _dos_driveremovable(int drive);
int _dos_getdrivemap(int drive),
char far *truename(char far *s, char far *d);
WORD get_fat_entry(int drive, DPB far *dpb, WORD cluster);
int read_sectors(int drive, BYTE far *buf, int sectors, DWORD first_sector);
#endif /* DISKSTUF_H */
```

In DISKSTUF.C, Listing 8.4, `get_dpb` checks for removable media and installs an INT 24h critical error handler. This is because the DOS Get DPB function (INT 21h AH=32h) hits the disk. In the absence of an INT 24h critical error handler like the one provided in Listing 8.4, calling Get DPB for drive A: for example, can produce an annoying "Not ready reading drive A / Abort, Retry, Fail?"

message. Furthermore, calling Get DPB for drive B:, if the drive is currently assigned to drive A: produces the equally annoying "Insert diskette for drive B: and press any key when ready" message. This issue is discussed at length in, as usual, Chapter 16 of Geoff Chappell's *DOS Internals*.

Listing 8-4: DISKSTUF.C

```
/*
DISKSTUF.C -- Some functions and structures for low-level disk access
Andrew Schulman, July 1993
*/

#include <stdlib.h>
#include <stdio.h>
#include <ctype.h>
#include <dos.h>
#include "diskstuf.h"

int _dos_driveremoveable(int drive)
{
    int retval;
    _asm mov ax, 4408h
    _asm mov bl, byte ptr drive
    _asm int 21h
    _asm jnc ok
    return 0;           // treat error as non-removeable
ok:
    _asm mov retval, ax
    return (! retval);  // turn around so non-removeable = 0
}

int _dos_getdrivemap(int drive)
{
    _asm mov ax, 440Eh
    _asm mov bl, byte ptr drive
    _asm int 21h
    _asm jc error
    _asm cmp ax, 0                  // only one drive number
    _asm je error
    _asm xor ah, ah
    _asm mov word ptr drive, ax     // active drive number
error:
    return drive;
}

typedef struct {
#ifdef __TURBOC__
    unsigned short bp,di,si,ds,es,dx,cx,bx,ax;
#else
    unsigned short es,ds,di,si,bp,sp,bx,dx,cx,ax;   /* PUSHA order */
#endif
    unsigned short ip,cs,flags;
    } REG_PARAMS;

/*************************************************************/
typedef void interrupt (far *INTVECT)();
static volatile int failed = 0;
static INTVECT old_int24 = (INTVECT) 0;

void interrupt far crit_err(REG_PARAMS regs) // INT 24h handler
{
    REG_PARAMS *pregs = &regs;
    pregs->ax = 3;
    failed++;
}

void watch_crit_err(void)
{
    failed = 0;
```

```
    old_int24 = (INTVECT) _dos_getvect(0x24);
    _dos_setvect(0x24, (INTVECT) crit_err);
}
void unwatch_crit_err(void) { _dos_setvect(0x24, old_int24); }
int get_failed(void)        { return failed; }
void reset_failed(void)     { failed = 0; }
/*************************************************************************/
DPB far *get_dpb(int drive)
{
    DPB far *dpb = (DPB far *) 0;
    // if drive removeable and not mapped, fail
    if (_dos_driveremoveable(drive))
        if ( dos_getdrivemap(drive) != drive)
            return (DPB far *) 0;
    // install temp crit-error handler for duration of 21/32 call
    watch_crit_err();
    // call newly-documented DOS Get DPB function
    _asm push ds
    _asm mov ah, 32h
    _asm mov dl, byte ptr drive
    _asm int 21h
    _asm mov dx, ds
    _asm pop ds
     asm cmp al, 0FFh
    _asm je fini
    _asm mov word ptr dpb+2, ds
     asm mov word ptr dpb, bx
fini:
    // remove temporary crit-err handler
    unwatch_crit_err();
    // "failed" is set inside Get DPB by crit-err handler
    return failed? ((DPB far *) 0) : dpb;
}
char far *truename(char far *s, char far *d)    // get canonical pathname
{
    /* INT 21h AH=60h doesn't like leading or trailing blanks */
    char far *s2;
    while (isspace(*s)) s++;            // ltrim
    s2 = s; while (*s2) s2++; s2--;     // go to end
    while (isspace(*s2)) *s2-- = 0;     // rtrim
    /* Apparently some versions of DR DOS insist on ES:DI != DS:SI */

    _asm push di
    _asm push si
    _asm push ds
    _asm push es
    _asm les di, d
    _asm  ds si, s
    _asm mov ah, 60h
    _asm  nt 21h
    _asm pop es
    _asm pop ds
    _asm pop si
    _asm pop di
    _asm jc error
    return d;
error:
    return (char far *) 0;
}
typedef struct {
    DWORD diStartSector;
    WORD diSectors;
    BYTE far *diBuffer;
```

```
    } DISKIO,
int read_sectors(int drive, BYTE far *buf, int sectors, DWORD first_sector)
{
    DISKIO diskio, far *pdiskio = &diskio,
    diskio.diStartSector = first_sector,
    diskio diSectors = sectors;
    diskio diBuffer = buf;
    // INT 25h/26h are obsolete, should instead use generic
    // IOCTL functions 21/4400/0861 and 21/4400/0841.
    _asm push ds
    _asm mov al, byte ptr drive
    _asm lds bx, pdiskio
    _asm mov cx, 0FFFFh
    _asm mov dx, 0
    _asm int 25h
    _asm jc do_fail
    _asm popf           // INT 25h, 26h leave flags on stack
    _asm pop ds
    return 1,
do_fail
    _asm popf
    _asm pop ds
    return 0,
}
// get_fat_entry() hides differences between 12-bit and 16-bit FATs
// returns 12-bit FAT EOF indicators (e.g., 0xFFD) in 16-bit form (0xFFFD)
WORD get_fat_entry(int drive, DPB far *dpb, WORD cluster)
{
    static WORD *fat_sect = (WORD *) -1,
    static WORD prev_drive = (WORD)  1,
    static DPB far *prev_dpb = (DPB far *) -1L,
    static WORD prev_sect = (WORD) -1,
    WORD first_fat_sect, entry_per_sect, sect, fat_size,
    // One-time initialization of buffer, allocate 2 sectors because
    // this may be needed for 12-bit FAT if a FAT entry slops over
    // two sectors. (Yuch!)
    if (fat_sect == (WORD *) -1)
        if (! (fat_sect = (WORD *) malloc(dpb->bytes_per_sect * 2)))
            fail( "insufficient memory");
    if (_osmajor >= 4)
        first_fat_sect = dpb->vers.dos4.first_dir_sector -
            (dpb->copies_fat * dpb->vers.dos4.sectors_per_fat),
    else
        first_fat_sect = dpb->vers.dos3.first_dir_sector -
            (dpb->copies_fat * dpb->vers.dos3.sectors_per_fat),
    fat_size = (dpb->highest_cluster >> 12 == 0) ? 12 : 16,
    if (fat_size == 12)
        sect = first_fat_sect + (((cluster * 3) / 2) / dpb->bytes_per_sect);
    else
    {
        entry_per_sect = dpb->bytes_per_sect / 2;
        sect = first_fat_sect + (cluster / entry_per_sect);
    }
    // Don't reread if same sector as last time (assumes of course
    // that some TSR hasn't modified the sector in the meantime!)
    if (! (drive == prev_drive && dpb == prev_dpb && sect == prev_sect))
    {
        int num_sect = (fat_size == 12) ? 2 : 1;    // for possible slop
        if (! read_sectors(drive, (BYTE far *) fat_sect, num_sect, sect))
            fail("can't read FAT");     // could try FAT #2
    }
    prev_sect = sect, prev_drive = drive; prev_dpb = dpb,
```

```
    if (fat_size == 12)
    {
        BYTE *fat = (BYTE *) fat_sect;
        WORD ofs   = ((cluster * 3) / 2) % dpb->bytes_per_sect,
        WORD retval = *((WORD *) &fat[ofs]);
        if (cluster & 1)          // odd cluster #
            retval >>= 4;         //     take top 12 bits
        else                      // even cluster #
            retval &= 0x0FFF;     //     take bottom 12 bits
        // return 12-bit FFD-FFF as 16-bit FFFD-FFFF
        return (retval >= 0x0FF0) ? (retval | 0xF000) : retval;
    }
    else    // gosh, 16-bit FATs are easy
        return fat_sect[cluster % entry_per_sect];
}
```

In addition to get sector and get fat entry, DISKSUP.C also contains the function read sectors, which uses INT 25h (or the newer-style int introduced in Compaq DOS 3.31: INT 25h and 26h are DOS Absolute Disk Read and Write functions. According to the MS-DOS programmer's reference, the generic IOCTL functions INT 21h AX=4402h CX=0863h Read Track on Logical Drive and CX=0864h Write Track on Logical Drive are now the preferred functions for accessing disk sectors. In the source code for example, FORMAT relies heavily on generic IOCTL. The disk read/write generic IOCTL calls also largely eliminate the need for directly messing with BIOS INT 13h calls. Both INT 25h/26h and the generic IOCTL disk functions just call down to the block device driver to perform the device-relative needed to read the disk. As shown by running the FAT program under IN-BOARD DISK SCAN, this part of our configuration: this means calling BIOS INT 13h

```
C:\UNDOC2\CHAP8>cmdspy compile disk c: fat c: 7470

.
25  Abs Disk Read drv 02, at sectr 0000001E, 0001 sctrs
04 - input
1302  Read 09 sctrs  drv 80, head 00, sctr 01, trk 04 to 1685:0000
25  Abs Disk Read drv 02, at sectr 0000001F, 0001 sctrs
04 - input
1302  Read 09 sctrs  drv 80, head 01, sctr 07, trk 04 to 1705:0000
.
```

The INT-SPY output shows that INT 25h calls device driver function 4 Read, which in turn calls INT 13h AH=2.

However, for a RAM disk, for example, the device driver would certainly *not* call INT 13h! Instead, it would read and write sectors by accessing memory. The construction of RAM disks is an interesting topic that we won't take up further here. For an introduction, see the chapter on RAM disk construction in *Writing MS-DOS Device Drivers* and supplement this with an exploration of the various RAM disks in common use, such as the issue of extended memory. For example, on 80286-based PCs, Microsoft's RAMDRIVE.SYS uses the undocumented LOADALL instruction. IBM's VDISK.SYS uses protected-mode programming. Later on, we may look at VDISK. Later on, we may look at how to detect whether a given drive is a RAM disk.

Given the sector number and DPB information to figure out which FAT sector to read for. Then, sector offset in that sector, get fat entry. Last used: the function calls read sector to read the FAT sector into memory and indexes into the FAT sector: this is trivial for 16-bit FATs and more complex for 12-bit FATs. For 12-bit FATs, the code also has to worry about a FAT entry spanning two sectors, which will allocate space for two sectors and for 12-bit FATs reads in two sectors.

In any case, the FAT is a linked list of clusters that threads the pieces of each file together and tells us where space is available. Determine where the very first cluster for any specified file is located, and we can access every byte of it. How do we find the starting cluster found? That's done by the directory structure, to which we now turn.

DOS Directory Structure

Every disk volume (that is, each diskette in drives with removable media or each partition of a non-removable media) has a root directory which is the starting point for translating human-oriented file names into system-oriented cluster numbers.

The root directory immediately follows the FAT and precedes the data storage area. Its size is established when the disk is formatted. Unlike non-root directories which are just files, the root directory can never change size. A typical root directory size for a 360K floppy is 112 entries; for a hard disk it's usually larger (typically 512 entries). For a floppy disk, DOS/MS won't accept a BPB calling for more than 240 root directory entries. Neither will it accept values other than 2 for the number of FATs, 1 for the number of reserved sectors, or a sector size other than 512 bytes.

Besides having a fixed size, the root directory has a number of important differences from non-root directories. The root directory is not accessible from the FAT. It starts from one sector after the root directory to the next, so you cannot walk the FAT as with non-root directories. Instead, all root directory sectors are contiguous. You can use values from the DPB to compute the number of root directory sectors, as shown in the simple program NAMCLUST.C (Listing 8.5; see the code in do_cluster() to handle the case of cluster == 0).

As seen from the DIR_ENTRY structure in DISKSTU2.H (Listing 8.3), each directory (whether one of the root or has a subdirectory) consists of a 32-byte structure. This structure displays visible on a hex dump. Directory structure. Figure 8.4 shows the DEBUG command output for sector 5B4Dh from drive C:. (In this section, the dumped sector, the DIR command, and the sector 5B4Dh contained a directory for C:\UNDOC2\CHAP8 was used as input to the NAMCLUST program. A few more comments about Figure 8.4 are in order. The filenames FILES.C and FILES.EXE are visible within this directory, as are the standard . and .. files for the current and parent subdirectories.

Figure 8.4 was generated on a system running Stacker. The directory structure shown is not data inside a STACVOL.000 file on drive D and stored physically on disk C. The root on C appears to be on drive C, so I make the point once more. The system data need not reside on disk in any fixed way, because a block device driver can set up the necessary DOS file system structures on demand.

Figure 8-4: A DOS Directory Structure

```
C:\UNDOC2\CHAP8>namclust .
C:\UNDOC2\CHAP8  => 1448 (sect 23373, 0x00005b4d)

C:\UNDOC2\CHAP8>debug
-L 1000 2 5b4d 1
-d 1000
7CCD:1000  2E 20 20 20 20 20 20 20-20 20 20 10 00 00 00 00                .
7CCD:1010  00 00 00 00 00 00 20 B5-73 1A A8 05 00 00 00 00   .      . s
7CCD:1020  2E 2E 20 20 20 20 20 20-20 20 20 10 00 00 00 00
7CCD:1030  00 00 00 00 00 00 20 B5-73 1A 12 00 00 00 00 00   .      . s
7CCD:1040  46 49 4C 45 53 20 20 20-43 20 20 20 00 00 00 00   FILES   C
7CCD:1050  00 00 00 00 00 00 5B 70-E7 1A AA 22 3C 19 00 00      .  [p  . <
7CCD:1060  46 49 4C 45 53 20 20 20-45 58 45 20 00 00 00 00   FILES   EXE
7CCD:1070  00 00 00 00 00 00 17 B9-72 1A 53 05 52 10 00 00          . r S R
-q

C:\UNDOC2\CHAP8>dir
 Volume in drive C is ...
 Directory of C:\UNDOC2\CHAP8

.            <DIR>      03-19-93  10:41p
..           <DIR>      03-19-93  10:41p
FILES    C         6460 07-07-93   2:02p
FILES    EXE       7506 03-18-93  11:08p
       4 file(s)      13966 bytes
```

```
00h     BYTE name[8]            "FILES
08h     BYTE ext[3]             "C  "
0Bh     BYTE attrib             20
0Ch     BYTE reserved[10]       00    00 (used for OS/2 EAs)
16h     WORD time               5B 70
18h     WORD date               E7 1A
1Ah     WORD cluster            AA 22 (22AAh = 8874 dec)
1Ch     DWORD size              3C 19 00 00 (193Ch = 6,460 bytes)
```

In this structure, the first byte of the filename field has special significance, as does the attribute byte. If the first byte of the filename is E5h, this indicates that that entry refers to a file which has been deleted and whose space can be reused for a new file or directory entry. (Or possibly undeleted if you get to it before DOS starts looking for space.) The last directory entry written and use this rather than searching from the beginning of the directory, the starting point for seeking directory entries. This increases the speed of file creation, especially in directories with many entries. If the first byte is 05h, this indicates that the first character of the filename is actually E5h. (Starting with DOS 3.0 and higher, I made it the first character of the filename.) A 00 byte indicates that neither this entry nor any subsequent one in the directory has ever been used. This permits searches to stop as soon as a 00 byte is found. It also means that a stray 00 byte can make it appear as if not just one, but all directories following it have disappeared from your disk.

The choice of the value E5h was chosen to indicate a deleted directory entry according to Peter Norton, because it is unlikely to occur in the first place and might help him to know the original 8-inch floppy disk format. (A Norton shipped to me matched with that byte. Well, I still like indicating that a directory entry is available for use. Programs deleting files right out of the box would be ready to accept files when MS-DOS was installed. Of course, this could cause problems with many other CP/M artifacts. The FAT still needed cleaning up by built-in CHKDSK or external pre-IBM DOS. The zero byte to indicate unused directory space did not appear until the beginning of DOS.

Bytes 12h–15h are reserved under DOS. If the entry refers to a file or a subdirectory, 16h–17h or 18h–19h is a cluster number. DOS uses these bytes to provide access to the start of the file. The meaning of bytes 14h–15h is undefined under DOS. OS/2 uses two of these reserved bytes as a handle to associated extended attributes. EAs are stored in OS/2 support files called EA database files. As Chapter 4 notes, DOS programs running under OS/2 can access these EAs with INT 21h AH = 71h. One of the extended attributes can be a long filename.

Long Filenames in "Chicago"

For the first time, Microsoft's important new "Chicago" operating system (DOS 7.0, Windows 4) supports long filenames. For example, "This is a valid filename under Chicago" is a valid filename under Chicago.

Of course, Microsoft had to implement these long filenames in a way that didn't break existing applications. Furthermore, media written under Chicago must still be usable under old versions of DOS and Windows.

Every long filename in Chicago has a unique short alias, such as "THISIS~1". In fact, it appears that Chicago will be case-preserving (though case-insensitive), so essentially *all* files and directories created under Chicago will have two forms. For example, "copy foo.bar FooBar.Sk.doc" would create both a standard "FOOBARSK.DOC" directory entry and, even though FOOBARSK.DOC fits within the standard 8.3 filename confines, a second, case-preserving "FooBar.Sk.doc" entry.

Judging from a prerelease version, Chicago implements long filenames in a substantially different way from OS/2 EAs. Whereas OS/2 uses two reserved bytes in the directory entry

to store an EA handle (one of the EAs can be a long filename), Chicago instead uses a series of directory entries to store the long case preserving filename, following these with the unique short filename alias. For example

```
I:\>md foo
I:\>cd foo
;; Note below that the directory name in the prompt is lower case
I:\foo>copy con this is a.test of foo barsky tester
;; Note below that DIR shows both the long/lower name and short/upper alias
I:\foo>dir this* *
THISIS~1 TES             7  09-13-93  14:55 this is a.test of.foo barsky.tester
;; Now use NAMCLUST (Listing 8-5) to see how this appears in the directory
I:\foo>namclust
I:\FOO => 2 (sect 439, 0x000001b7)
;; SECTDUMP is a sector-dump program on the UndocDOS disk
I:\foo>sectdump > 439 1
Sector 00000439 (000001B7h)
0000   2E 20 20 20 20 20 20 20 20 20 20 10 00 00 00 00 |.          .....|
0010   00 00 00 00 00 00 F1 76 2D 1B 02 00 00 00 00 00 |       .v-. . .|
0020   2E 2E 20 20 20 20 20 20 20 20 20 10 00 00 00 00 |..          .....|
0030   00 00 00 00 00 00 F1 76 2D 1B 00 00 00 00 00 00 |       v-       |
0040 ! 12 68 79 2E 74 65 73 74 65 72 00 0F 00 B9 FF FF |  ky tester     |
0050   FF FF FF FF FF FF FF FF FF FF 00 00 FF FF FF FF |                .|
0060   01 74 68 69 73 2E 69 73 2E 61 2E 0F 00 B9 74 65 | this is a    te|
0070   73 74 2E 6F 66 2E 66 6F 6F 2E 00 00 62 61 72 73 |st.of foo   bars|
0080   54 48 49 53 49 53 7E 31 54 45 53 20 00 00 00 00 |THISIS~1TES     |
0090   00 00 2D 19 00 00 F8 76 2D 1B 03 00 07 00 00 00 |       v        |
```

The long filename appears in place directly adjacent to the short form. SECTDUMP shows that the long filename is spread across two directory entries, which immediately precede the short form. Larry Seltzer discusses the pros and cons of this approach in an excellent article in *PC Week* (September 20, 1993). Each long filename entry consists almost entirely of part of the long filename itself, ignoring the normal directory entry fields, except for the attribute byte, which is 0Fh. Programs that directly manipulate directory entries, such as CLUSTNAM and NAMCLUST, can use (p_attrib & 0x0F) to skip over these strange long filename entries. Otherwise these programs will misinterpret part of the ASCII name as, for example, the file size or date! Of course, this implementation may change in the final release, and you should not rely on this scheme.

Few programs poke their noses into directory entries though, so discussing the implementation of long filenames before discussing the standard INT 21h interface is putting the cart before the horse. Most DOS programs open and find files, get the current directory, and so on, using normal INT 21h calls. Fortunately, programs like CLUSTNAM and NAMCLUST are the exception rather than the rule.

Let's say a DOS program calls INT 21h AH=47h to get the current directory. According to Microsoft's DOS 6.0 programmer's reference, a program needs a buffer of at least 64 bytes, which is large enough to contain the largest possible path. The program now finds itself running under Chicago, where a single directory, not to mention the entire path, is easily larger than 64 bytes (the limit is 254 characters for the filename, and 259 characters for the pathname). What happens?

The program gets the short form, of course. Otherwise, Chicago would break every DOS program that had obeyed the rules and allocated as little as 64 bytes in which to receive the current directory string. So developers don't have to worry about Microsoft breaking old programs with long filenames. Furthermore, Microsoft is taking care so that, as much as possible, an end-user sees long filenames even when a program sees the short ones. For example, it intends for the Windows common file dialogs (COMMDLG.DLL) to work this way.

However, programs will eventually want to know full filenames. Getting the long version instead of the short alias requires a new set of functions. Windows programs will use Win32 API functions such as GetCurrentDirectory and CreateFile. A DOS program will be able to use a new set of INT 21h AX=71XXh functions, where the subfunction in AL is the same as the old DOS AH function number. For example, because the old DOS Get Current Directory function is INT 21h AH=47h, the new one that knows about long pathnames is INT 21h AX=7147h, while the other registers are identical to the old call. The buffers pointed to by DS:SI must be large enough to receive the maximum-allowed path. Programs can use the new INT 21h AX=4302h Get Volume Information function (see below) to get the length of the maximum allowed path.

(Incidentally, there is a new 21 7160 equivalent to the old 21 60 undocumented Truename function. Also, it isn't clear if Chicago will provide functions to convert between long and short filenames.)

In addition to these new INT 21h AH=71h calls, Chicago also requires some new actions for INT 21h AH=57h (4=get last access date, 5=set last access date). Incidentally, Chicago neatly skips over the two OS/2 2.x actions for INT 21h AH=57h (see Chapter 4), which the protected-mode Interrupt 21h emulator marks as "reserved." This is important, because some early reports out of Chicago (*PC Week*, August 23, 1993) claimed that Chicago long filenames might involve some deliberate incompatibility with OS/2. The evidence here points in the exact opposite direction. It appears to be deliberately *compatible*, a welcome change from the deliberate incompatibility seemingly deliberately discussed in Chapter 1.

Another new DOS call is INT 21h AH=71h (FindClose). Whereas previous versions of DOS support only FindFirst and FindNext, Chicago requires FindClose because the Win32 programming interface (API) supports multiple simultaneous file finds. FindFirst (INT 21h AX=714Eh) returns a "search handle" which you must pass to FindNext (INT 21h AX=714Fh) and which you must close with FindClose.

Long filenames are not supported in the real-mode DOS boot code portion of Chicago, which runs before IO.SYS/IBMBIO.COM. This means that real-mode programs such as TSRs and device drivers cannot call the new long filename APIs if they run at system startup. Similarly, the few programs that use so-called "Single Application Mode" also won't be able to call the long filename APIs. To determine if the new APIs are available, a program can check the return values from the new 21 71 functions, or it can call the INT 21h AX=4302h Get Volume Information function. This new function returns information on the maximum pathname component length, whether the file system is case-preserving, and whether the long filename APIs are available. The function also returns the file-system name, which in the preliminary release was "LFAT".

Internally, Chicago's protected-mode DOS extender, the directory entry, and the one we're most interested in is the cluster word at offset 1Ah. This is the number for the file's first cluster. Recall from FAT that once you have the first cluster, the FAT chain gives you access to the

rest of the file. The cluster word in the directory entry is what DOS uses to translate a file name to a location on disk.

NAMCLUST.C listing 8-5 shows one way to use the cluster number and directory structure to translate names to locations. NAMCLUST takes a pathname, the name of a directory, or its command line and displays the file's or directory's first cluster number. For convenience when using DEBUG to read sectors from disk, NAMCLUST also translates the cluster number to a hex sector number. For example:

```
C:\UNDOC2\CHAP8>namc ust
C:\UNDOC2 ==> 18 (sect 493, 0x000001ed)

C:\UNDOC2\CHAP8>debug
-L 1000 2 01ED 1
```

NAMCLUST.C doesn't illustrate the easiest way to turn a pathname into a cluster number. You'll see later on that the SFT entry for an open file contains the file's starting cluster number. Thus opening a file and then looking for the cluster number in the open file's corresponding SFT is simpler. You could do the same thing with DEBUG. Robert Hummel's *Undocumented DOS*, Chapter 3, shows how to use DEBUG to read starting clusters again without walking the FAT. However, the code in NAMCLUST.C uses the actual directory structures on disk and so better illustrates the workings of the DOS file system.

Run it with just a drive or dir's on the command line, for example, NAMCLUST C:. The program walks the entire directory structure, printing out a hierarchical list of every file and its starting cluster. For example, the following shows C:\BORLAND\INCLUDE\SYS and other files:

```
C:\UNDOC2\CHAP8>namcclust c:
. . .
BORLAND  => 172 (sect 2957, 0x00000b8d)
   INCLUDE ==> 175 (sect 3005, 0x00000bbd)
      SYS ==> 176 (sect 3021, 0x00000bcd)
         LOCKING H   => 10797 (sect 172957, 0x0002a39d)
         STAT H ==> 10798  sect 172973, 0x0002a3ad)
         TIMEB H  => 10799 (sect 172989, 0x0002a3bd)
         TYPES H ==> 10800 (sect 173005, 0x0002a3cd)
      ALLOC H ==> 10711 (sect 171581, 0x00029e3d)
      ASSERT H  => 10712 (sect 171597, 0x00029e4d)
      BCD H ==> 10713 (sect 171613, 0x00029e5d)
      BIOS H   => 10715 (sect 171645, 0x00029e7d)
      .     etc
```

In NAMCLUST.C the variable local_cc stores the string of the entire disk.

Listing 8-5. NAMCLUST.C

```
/*
NAMCLUST C -- Convert file name to starting cluster
Andrew Schulman, July 1993

Overall structure
main
    truename -- to get canonical filename
    get dpb
    do_cluster  - process a directory cluster, start with root dir < +
        read_sectors (if it's a root directory)                      |
        read_cluster                                                 |
            read_sectors (INT 25h)                                   |
        do_dir                                                       |
            printf -- success!  print results                        |
            do_cluster    partial match, recurse to next level       +
            get_fat_entry -- get next cluster of directory
        fail  -- no such file!
*/

#include <stdlib.h>
```

```
#include <stdio.h>
#include <string.h>
#include <ctype.h>
#include <dos.h>
#include  diskstuf.h"

// see Hummel, Assembly Language Lab Notes, p. 88
#define CLUSTER_TO_LSN(clust)   \
    ((((DWORD) (clust) - 2) * sect_per_clust) + first_sect)

void do_cluster(WORD cluster),
void do_dir(WORD cluster, DIR_ENTRY *buffer),
void read_cluster(int drive, BYTE far *buffer, WORD cluster),

static STRING glob_name[64] = {0},
static DPB far *glob_dpb,
static WORD want_cluster = 0xFFFF,
static WORD bytes_per_clust = 0, sect_per_clust = 0, first_sect = 0,
static int level = 0, glob_num_dir = 0, glob_drive,
static int num_levels = 0;
static char canon[128];
static int do_all = 0;

void fail(const char *s) { puts(s); exit(1); }

main(int argc, char *argv[])
{
    char pathname[64],
    char *s, *s2,
    int i, part;

    if (argc < 2)
        fail("usage: namclust [pathname or drive:]");

    for (i=0; i<64; i++)
        glob_name[i] = (STRING) malloc(16);

    // program uses DOS 3.31 style of INT 25h
    if ((_osmajor < 3) || (_osmajor == 3 && _osminor < 31))
        fail("This program requires DOS 3.31 or higher");

    if (strlen(argv[1]) == 2 && argv[1][1] == ':')
    {
        do_all++,
        num_levels = 0xffff,
        strcpy (canon, strupr(argv[1]));
    }
    else
    {
        if (! truename(argv[1], canon))
            fail("can't get truename"), // might be JOINed drive
        if (canon[1] != ':')
            fail( Sorry, this doesn't work on network-redirector drives"),

        for (part=0, s=canon, s2=pathname; ; s++)
            if ((*s == '\0') || (*s == '\\'))
            {
                *s2 = '\0',
                strcpy(glob_name[part], pathname);
                part++,
                if (*s == '\0')
                    break;
                s2 = pathname,
            }
            else
                *s2++ = *s;

        num_levels = part - 1,
        level = 1;
    }
```

```
    glob_drive = canon[0] - 'A';
    if (! (glob_dpb = get_dpb(glob_drive+1)))
        fail("can't get DPB");

    sect_per_clust = glob_dpb->sectors_per_cluster + 1;
    bytes_per_clust = glob_dpb->bytes_per_sect * sect_per_clust;
    first_sect = glob_dpb->first_data_sector;
    glob_num_dir = bytes_per_clust / sizeof(DIR_ENTRY);
    do_cluster(0);                  // kick-start search
}
void do_cluster(WORD cluster)
{
    BYTE *buffer;
    if (cluster == 0)   // phony cluster # for root directory
    {
        int num_sect;
        buffer = (BYTE *) calloc(glob_dpb->max_root_dir, sizeof(DIR_ENTRY));
        if (! buffer)
            fail("insufficient memory");
        num_sect = (glob_dpb->max_root_dir * sizeof(DIR_ENTRY)) /
            glob_dpb->bytes_per_sect;
        read_sectors(glob_drive, buffer, num_sect,
            (_osmajor >= 4) ? glob_dpb->vers_dos4.first_dir_sector :
                              glob_dpb->vers_dos3.first_dir_sector);
    }
    else
    {
        if (! (buffer = (BYTE *) calloc(bytes_per_clust, 1)))
            fail("insufficient memory");
        read_cluster(glob_drive, buffer, cluster);
    }
    do_dir(cluster, (DIR_ENTRY *) buffer);
    // shouldn't get here: can't free!
    if (do_all)
        free(buffer);
    else
        fail("can't find file");    // error if get here
}
void do_dir(WORD cluster, DIR_ENTRY *buffer)
{
    DIR_ENTRY *dir, *p;
    char name[16], *s;
    WORD next, num_dir;
    int entry, i;

    dir = (DIR_ENTRY *) buffer;
    num_dir = (cluster == 0) ? glob_dpb->max_root_dir : glob_num_dir;

    for (entry=0, p=dir; entry<num_dir; p++, entry++)
    {
        if (p->name[0] == '\0') return;     // end of dir
        if (p->name[0] == 0xE5) continue;   // deleted entry
        if (p->name[0] == '.')  continue;   // don't bother with . and ..

        // looks like Chicago uses these for long-filename entries
        if (p->attrib == 0x0F) continue;

        memcpy(name, p->name, 8); name[8] = 0;
        s = name; while (*s && *s != ' ') s++; *s = '\0';
        if (name[0]   0x05) name[0] = 0xE5;    // 0xE5 is valid first char
        if (p->ext[0] != ' ')
        {
            strcat(name, ".");
            strncat(name, p->ext, 3);
            s = name; while (*s && *s != ' ') s++, *s = '\0';
        }
```

```
        if (do_all || strcmp(name, glob_name[level]) == 0)  // got match
        {
            if (do_all || level == num_levels)              // done
            {
                DWORD sector = CLUSTER_TO_LSN(p->cluster);
                char *s;
                if (do_all)
                {
                    int i;
                    for (i=0; i<level; i++)
                        printf("   ");
                    s = name;
                }
                else
                    s = canon;
                printf("%s ==> %u (sect %lu, 0x%08lx)\n",
                    s, p->cluster, sector, sector);
                if (!do_all)
                    exit(0);
            }
            if (p->attrib & DIRECTORY_ATTR)  // already know not . or ..
            {
                level++;
                do_cluster(p->cluster);      // if directory, recurse
                level--;                     // for do_all
            }
        }
    }

    /* locate next directory cluster
    if (next = get_fat_entry(glob_drive, glob_dpb, cluster)) < 0xFFF0)
        do_cluster(next);
}

void read_cluster(int drive, BYTE far *buffer, WORD cluster)
{
    DWORD sector;
    if (cluster == 0)           sector = CLUSTER_TO_LSN(cluster);
    else if (osmajor >= 4)      sector = glob_dpb->vers_dos4.first_dir_sector;
    else                        sector = glob_dpb->vers_dos3.first_dir_sector;
    if (!read_sectors(drive, buffer, sect_per_clust, sector))
        fatal("can't read cluster");
}
```

NAME.LSN works by reading the disk's directory structure, trying to match the name of the specified file or directory.

The program calls the truename function (INT 21h AH=60h) in DISKSTUF.C (Listing 8.4) to canonicalize the name specified on its command line (see "Finding a True Name").

Finding a True Name

In the MS-DOS file system, things may not be what they seem. A file called C:\FLOPPY\FOO.BAR may actually be located on a joined floppy disk in drive A:, and a subdirectory called F:\SOURCES may actually be located on a network file server (probably not even running MS-DOS) in a directory called \\BIN\EXPORT\DOS. A canonical (true) path string resolves all these logical (that is, non-physical) drive and path references to an absolute pathname, taking account of any renaming due to JOIN, SUBST, or network redirections.

Fortunately, there is a DOS function that provides a true canonical pathname: undocumented INT 21h function 60h (Resolve Path String to Canonical Path String). This corre-

sponds to the undocumented TRUENAME command in COMMAND.COM in DOS 4.01 and higher (see Chapter 10). For example

```
C:\UNDOC2>truename foo.bar
C:\UNDOC2\FOO.BAR

C:\UNDOC2>subst g: c:\undoc2

C:\UNDOC2>truename g:\foo.bar
C:\UNDOC2\FOO.BAR

C:\UNDOC2>c:\dos\join a: c:\floppy

C:\UNDOC2>truename c:\floppy\foo.bar
A:\FOO.BAR

C:\UNDOC2>rem E: and F: are network drives

C:\UNDOC2>truename f:\foo.bar
\\HOME\C\ANDREW\FOO.BAR

C:\UNDOC2>truename e:\*.exe
\\BIN\EXPORT\DOS\????????.EXE
```

Because G: is a SUBSTed alias for C:\UNDOC2, the true name for G:FOO.BAR is C:\UNDOC2\FOO.BAR. Likewise, because C:\FLOPPY is a JOINed alias for the A: drive, A:\FOO.BAR is the true name for C:\FLOPPY\FOO.BAR. F: is located on a Sun SPARCstation (made available to DOS using PC/TCP from FTP Software), and the \\ that starts off the truename of F:\FOO.BAR is the universal naming convention (UNC) indicating that this is a network drive.

It is important to realize, however, that the file FOO.BAR need not necessarily exist. This is a source of tremendous confusion about what function 60h and the TRUENAME command do. The truename function and TRUENAME command deal with *path names*, not with actual files. This is important for disk utilities such as NAMECLIST because it provides an easy way of determining that the user has specified a device with which the program can work. Simply examining the specified drive letter such as C: or A: tells you nothing about the actual drive involved. It is also useful sometimes to have some assistance from the operating system in interpreting complex pathnames with many .. and subdirectories.

```
C:\UNDOC2>truename foo\bar\..\..\..\..\..
C:\
```

The undocumented TRUENAME command in COMMAND.COM in DOS 4.0 and higher is simply a wrapper around undocumented function 60h, which became available in DOS 3.0. You can call function 60h using the truename() function from DISKSTUF.C (Listing 8.4). Like most of the code in this chapter, the truename() function in DISKSTUF.C is only callable from a real mode DOS program. To call INT 21h, AH=60h from a protected mode Windows program, you need to use the techniques from Chapter 3 of this book. In particular, Listing 3.20 shows a protected mode version of truename() that uses DPMI. This is important because the normally well-informed *Microsoft Systems Journal* claimed (July-August 1992) that, unfortunately, TrueName cannot be called from Windows." Can too!

One problem with function 60h is its slightly odd interaction with JOIN. If you JOIN A: C:\FLOPPY, then while TRUENAME C:\FLOPPY\FOO.BAR works, TRUENAME A:FOO.BAR gets an "invalid drive specification" message! Meanwhile, function 60h does seem to work

properly with the odd ASSIGN command. For example, if you ASSIGN a=c, then TRUENAME A:FOO.BAR properly returns C:\FOO.BAR.

Another potential problem is that function 60h hits the disk. In some situations, accessing the Current Directory Structure might be preferable to function 60h. With the exception of its coexistence with ASSIGN, function 60h relates fairly directly to the CDS. For any drive n:, the output of function 60h for the string "n:." (that is, for the subdirectory) matches cds[drive n:].current_path. This point will make more sense when we discuss the CDS in detail, later in this chapter.

TRUNAM.C is a small sample program on the accompanying disk that runs truename() in a loop over the current directory for each drive on your system. The result is similar to that of the ENUMDRV program, shown later in Listing 8-11. Apparently there may be problems calling INT 21h AH=60h repeatedly under NetWare.

After calling truename, NAMCLUST next calls get_dpb() to retrieve the DPB for the specified drive. NAMCLUST uses the DPB to determine values such as the number of directory entries in a directory cluster and to locate the sector for the root directory. NAMCLUST then calls do_cluster() to look for the pathname component in the root directory. For root directories, do_cluster() reads in the entire root directory. Root directories have a fixed number of entries, which is given in the DPB, so don't require a loop around the DAY. For non-root directories, do_cluster() reads a single directory cluster into memory and then calls do_dir() to process the directory cluster.

Inside do_dir(), each directory entry is checked to see if the name matches the current portion of the pathname the user specified. If NAMCLUST finds a match at the end of the specified pathname, it is successful. If a match is found in the middle of the pathname, do_dir() returns to do_cluster(), which reads the next cluster of the directory. If there are no more clusters, do_cluster() returns to do_dir(), which returns to NAMCLUST. If NAMCLUST arrives at the bottom of the root directory without a match, the program has failed to match the specified pathname. Therefore, no such pathname exists.

Here's the trick: NAMCLUST knows how to turn pathnames into starting cluster numbers. For example, you could boot DOS, code only the front end of LIST.C (Listing 8-2) to produce a more useful program that accepts pathnames rather than cluster numbers, displayed a file or directory's possibly fragmented FAT chain.

It is also possible to work in the opposite direction. Given a starting cluster number, this program could reconstruct the corresponding pathname. This will be useful later when this chapter examines the DOS System File Table (SFT). The SFT contains only the name and extension of a file, without any path information. However, the SFT does contain the starting cluster number for any open file, and you can use this to generate the full pathname. Unfortunately, this CLUSNAM operation can take a long time. For example, the Norton Utilities NU program uses an "Information on item" option. Choosing this for a root directory causes NU to put up "Working, one moment please..." messages and grind away for a few seconds. Potentially, every subdirectory on the disk must be examined to match a cluster number.

CLUSNAM.C (Listing 8-6), the opposite of NAMCLUST.C (Listing 8-5), takes a drive and cluster number on its command line and walks the directory structure, trying to produce the corresponding pathname.

```
C:\UNDOC2\CHAP8>clusnam d: 28005
C:\UNDOC2\CHAP8\CHAP8.TXT
```

Running NAMCLUST confirms this:

```
C:\UNDOC2\CHAP8>namc.ust chap8.txt
C:\UNDOC2\CHAP8 TXT ==> 28005 (sect 112289, 0x0001b6a1)
```

The do_cluster and do_dir functions in CLUSTNAM.C differ those from in NAMCLUST. Rather than creating two slightly different versions of the same basic code, we should have written a more general subroutine library for manipulating DOS directory entries.

Listing 8-6: CLUSTNAM.C

```
/*
CLUSTNAM.C -- Convert cluster # to full pathname
See also NAMCLUST.C (Convert pathname to cluster #)
Andrew Schulman, July 1993

Program needs large model: bcc -ml clustnam.c diskstuf.c

Overall structure
main
    get_dpb
    search_for_cluster
        do_cluster <--------------+
            read_sectors           |
            read_cluster           |
                read_sectors       |
            do_dir                 |
                do_cluster --------+
                get_fat_entry
*/

#include <stdlib.h>
#include <stdio.h>
#include <string.h>
#include <ctype.h>
#include <dos.h>
#include "diskstuf.h"

void search_for_cluster();
void do_cluster(WORD cluster);
void do_dir(WORD cluster, DIR_ENTRY *buffer);
void read_cluster(int drive, BYTE far *buffer, WORD cluster);

void fail(const char *s) { puts(s); exit(1); }

static STRING glob_name[64] = {0};
static DPB far *glob_dpb;
static WORD want_cluster = 0xFFFF;
static WORD bytes_per_clust = 0, sect_per_clust = 0, first_sect = 0,
static int level = 0, glob_num_dir = 0, glob_drive;

main(int argc, char *argv[])
{
    int i;

    if (argc < 3)
        fail("usage: clusters [drive] [cluster]");

    // program uses DOS 3.31 style of INT 25h
    if ((_osmajor < 3) || (_osmajor == 3 && _osminor < 31))
        fail("This program requires DOS 3.31 or higher");

    for (i=0; i<64; i++)
        glob_name[i] = (STRING) malloc(16);

    glob_drive = toupper(argv[1][0]) - 'A';
    want_cluster = atoi(argv[2]);
    if (glob_dpb = get_dpb(glob_drive+1))
    {
        if (want_cluster <= glob_dpb->highest_cluster)
        {
            search_for_cluster();
```

```
            fail("couldn't find cluster"),  // error if get here
        }
        else
            fail("cluster number too high");
    }
    else
        fail("can't get DPB"),
    return 0,
}
void search_for_cluster(void)
{
    glob_drive = glob_dpb->drive;
    sect_per_clust = glob_dpb->sectors_per_cluster + 1,
    bytes_per_clust = glob_dpb->bytes_per_sect * sect_per_clust,
    first_sect = glob_dpb->first_data_sector;
    glob_num_dir = bytes_per_clust / sizeof(DIR_ENTRY);
    do_cluster(0),  // phony cluster 0 to kick start
}
void do_cluster(WORD cluster)
{
    BYTE *buffer,
    if (cluster == 0)   // phony cluster # for root directory
    {
        int num_sect;
        buffer   (BYTE *) calloc(glob_dpb->max_root_dir, sizeof(DIR_ENTRY));
        if (! buffer)
            fail("insufficient memory"),
        num_sect   (glob_dpb->max_root_dir * sizeof(DIR_ENTRY)) /
            glob_dpb->bytes_per_sect;
        read_sectors(glob_drive, buffer, num_sect,
            ( osmajor >= 4) ? glob_dpb->vers.dos4.first_dir_sector :
                              glob_dpb->vers.dos3.first_dir_sector),
    }
    else
    {
        if (! (buffer = (BYTE *) calloc(bytes_per_clust, 1)))
        {
            if (sizeof(void far *) != 4)
                puts( Hey, you should have compiled with large model!"),
            fail("insufficient memory"),
        }
        read_cluster(glob_drive, buffer, cluster);
    }
    do_dir(cluster, (DIR_ENTRY *) buffer);
    free(buffer),
}
void do_dir(WORD cluster, DIR_ENTRY *buffer)
{
    DIR_ENTRY *dir, *p;
    char name[9], ext[4],
    WORD next, num_dir;
    int entry, i;

    dir = (DIR_ENTRY *) buffer,
    num_dir = (cluster == 0) ? glob_dpb->max_root_dir : glob_num_dir;
    for (entry=0, p=dir, entry<num_dir, p++, entry++)
    {
        if (p->name[0] == '\0') return,     // end of dir
        if (p->name[0] == 0xE5) continue,   // deleted entry
        if (p->name[0] == '.')  continue,   // don't bother with . and ..

        // looks like Chicago uses these for long-filename entries
        if (p->attrib == 0x0F) continue;
```

```
        memcpy(name, p->name, 8), name[8] = 0,
        if (name[0] == 0x05) name[0] = 0xE5;    // 0xE5 is valid first char
        memcpy(ext, p->ext, 3);   ext[3] = 0;

        strcpy(glob_name[level], name),
        if (ext[0] != ' ' )  0)
        {
            strcat(glob_name[level], "."),
            strcat(glob_name[level], ext),
        }

        if (p->cluster == want_cluster) // found it!
        {
            char *s;
            int i,
            putchar(glob_drive + 'A'), putchar(':'); putchar('\\'),
            for (i=0; i<level; i++)
            {
                s = glob_name[i];       // trim spaces out of name
                while (*s) { if (*s != ' ') putchar(*s); s++; }
                putchar('\\'),
            }
            s = glob_name[level],       // trim spaces out of name
            while (*s) { if (*s != ' ') putchar(*s); s++; }
            putchar('\n');
            exit(0);                    // done: success!
        }

        if (p->attrib & DIRECTORY_ATTR) // already know not   or  .
        {
            level++,
            do_cluster(p->cluster),     // if directory, recurse
            level--,
        }
    }

    // locate next directory cluster
    next = get_fat_entry(glob_drive, glob_dpb, cluster),
    if (next < 0xFFF0)                  // end of dir
        do_cluster(next);
}

// see Nummel, Assembly Language Lab Notes, p  88
#define CLUSTER_TO_LSN(clust)   \
    ((((DWORD) clust)   2) * sect_per_clust) + first_sect)

void read_cluster(int drive, BYTE far *buffer, WORD cluster)
{
    DWORD sector;
    if (cluster != 0)       sector   CLUSTER_TO_LSN(cluster),
    else if (_osmajor >= 4) sector = glob_dpb->vers_dos4.first_dir_sector;
    else                    sector = glob_dpb->vers_dos3.first_dir_sector;
    if (! read_sectors(drive, buffer, sect_per_clust, sector))
        fail("can't read cluster");
}
```

Like NAMEFUNC, CLUNNAME uses the DISKSECT module from Listings 8-3 and 8-4. The program's overall structure is very similar to that of NAMEFUNC, except that where NAMEFUNC can clear out of the directory search as soon as it finds a mismatch, CLUNNAME must keep walking the entire subdirectory hierarchy until it finds a match.

The Drive Parameter Block (DPB)

The programs presented so far in this chapter all reached heavily on the DPB structure and get_dpb function in DISKSECT (Listings 8-3 and 8-4) to determine characteristics of a drive, such as its

bytes per sector, sectors per cluster, sectors per FAT, location of the first FAT, directory, data sectors, and so on. But we haven't said much yet about the DPB.

For each block device in the system, there's a Drive Parameter Block. These 32-byte blocks contain the information that DOS uses to convert cluster numbers into logical sector numbers for passing to the block device driver's Read and Write functions and to associate the device driver for that device with its assigned drive letter.

DOS creates the DPBs for each drive immediately after calling the driver's Initialize routine during the boot process. Recall from Chapter 7 how the DEVLOAD program, which mimics DOS operation when loading block device drivers, DPSs for the drivers by using IO.SYS or IBMBIO.COM normally flopped A: and B: together and then Disk C was created when IO.SYS initializes itself before processing CONFIG.SYS. Now, if any other block devices are created as one of the final steps of installing the device driver, while processing CONFIG.SYS.

The code that DEVLOAD uses that installs drivers uses the still undocumented INT 21h function 53h, passing a far pointer to the drive's BPB, see the Build Device Parameter Block function in DEVLOAD.C in Chapter 7, listing 7-38. You should recognize many of the fields in the DPB from our earlier discussion of the BPB. However, DOS does not take the BPB's description at face value. A copy of the BPB is used to create the DPB, and the pointer to part of the information returned by the driver's initialization device driver function 0. As you saw earlier for the built-in disk drives, the BPB is contained in the boot sector of each volume, and can change if a volume is changed. DOS uses the BPB to create the DPB to ensure the new volume's characteristics differ from the original values.

Not all DPBs have drive letters which have meaning associated with them; the exception to this is drive A: in a single floppy system. It's always assumed to exist, even when it doesn't. On the other hand, most systems have devices that manage block addresses, such as RAM disks, generally *do* have DPBs.

Each DPB is linked to the next one via a far pointer in the DPB structure. DEVHDR has the pointer's offset (and segment) to the end of this Drive Data Table. But while DPBs are chained together in a linked list, access to the head of the list, SYSVARS, is not as clear. The way to get the DPB for a given drive is to use the DOS undocumented INT 21h function 32h, which we saw in Chapter 7 as part of DEVLOAD's search for valid block device drivers and which is often used by disk programs such as Norton Utilities and PC Tools. Microsoft has finally documented this function in its *MS DOS Programmer's Reference*. Instead of referring to Microsoft, this function is only for MS DOS 5.0 and higher. Thus, as usual, by Microsoft documentation you can't write disk utilities that work under any previous version of DOS.

To see the information in DPBs, INT21C uses INT 21h function 32h to display capacity information for each drive in the system with a DPB. For example, on a system with a 1.2 megabyte floppy drive, a 360k floppy in the first drive, a 10 megabyte hard disk, and a 64k RAM drive installed, DEVLOAD will produce this as the program's output:

```
Drive A: 512 bytes/sector * 2 sectors/cluster =
         1024 bytes cluster * 354 clusters = 362496 bytes

Drive C: 512 bytes/sector * 8 sectors/cluster =
         4096 bytes cluster * 17648 clusters = 72286208 bytes

Drive E  512 bytes/sector * 1 sectors/cluster =
         512 bytes/cluster * 122 clusters = 62464 bytes
```

The program displays this information twice: once by walking the DPB linked list whose head is at offset 0 in SysVars, and once by calling INT 21h function 32h via get_dpb() from DISKSUP.C in Listing 8-4) for each drive < lastdrive.

You'll discover that, which would work better than walking the DPB chain for SUBST drives, for example, is to create the DPB from the drive's Current Directory Structure. For an illustration, see the function name_from_cds() in NUMDRV.C (Listing 8-11), which can retrieve a DPB with the expression curr_dir_drive->dpb.

Listing 8-7: DPBTEST.C

```
/*
DPBTEST.C -- uses undocumented INT 21h function 32h (Get DPB)
    to display bytes per drive, but first walks the DPB chain,
    showing the difference between the two access methods.
    A third access method gets the DPB from the CDS (see
    maybe_ram_disk() in ENUMDRV.C).
Andrew Schulman, updated July 1993
*/

#include <stdlib.h>
#include <stdio.h>
#include <dos.h>
#ifdef __TURBOC__
#include <dir.h>
#endif
#include  diskstuf.h"            // DPB structure, get_dpb()

void fail(const char *s) { puts(s), exit(1); }

void display(DPB far *dpb)
{
    DWORD bytes_per_clust =
        dpb->bytes_per_sect * (dpb->sectors_per_cluster + 1);
    printf("Drive %c: ", 'A' + dpb->drive);
    printf(  u bytes/sector *  , dpb->bytes_per_sect);
    printf(  u sectors/cluster = \n",
        dpb->sectors_per_cluster + 1),
    printf(            u bytes/cluster * ", bytes_per_clust),
    printf( lu clusters =  , dpb->highest_cluster - 1),
    printf( %lu bytes\n\n",
        bytes_per_clust * (dpb->highest_cluster - 1));
}

main()
{
    BYTE far *sysvars,
    DPB far *dpb;
    unsigned lastdrive;
    int i;

    if ((_osmajor < 3) ,  (_osmajor == 3 && _osminor < 2))
        fail("This program requires DOS 3.2 or higher");

    puts("Using DPB linked list");
    _asm mov ah, 52h            /* get SysVars */
    _asm int 21h
    _asm mov word ptr sysvars+2, es
    _asm mov word ptr sysvars, bx
    /* pointer to first DPB at offset 0h in SysVars */
    if (! (dpb = *((DPB far * far *) sysvars)))
        return 1;
    do {
        // don't show both A: and B: etc.
        if ((! _dos_driveremoveable(dpb->drive + 1)) ||
            (_dos_getdrivemap(dpb->drive + 1) == dpb->drive + 1))
            display dpb ,
        dpb   ( _osma or<4; ? dpb->vers dos3 next . dpb = dpb->vers.dos4.next;
    } while (FP_OFF(dpb) != 0xFFFF);

    // Another (better) method gets DPB pointer out of drive's CDS:
    // #define GET_DPB(drive) (currdir(drive)->dpb)
    // see maybe_ram_disk() #ifdef USE_CDS_DPB in Listing 8-11

    puts("Using INT 21h function 32h");
    _dos_setdrive(0xFF, &lastdrive),    // get lastdrive
    for (i=1; i<=lastdrive; i++)
```

```
        if (dpb = get_dpb(i))   // checks for removeable, critical error
            display(dpb);
    return 0;
}
```

This program brings up an important reason to use INT 21h function 32h instead of walking the DPB's linked list. For removable media, function 32h goes to the disk and therefore picks up the most current information. Walking the linked list merely gets whatever possibly stale DPB happens to be in memory. (Your access to 360K floppy disk drives A: removed, put in a 1.2 megabyte floppy without accessing it, and then walk the DPB linked list, you'll get the DPB for the 360K floppy. Function 32h would not make this mistake.)

One last hint: Function 32h hits the disk; see the disassembly of functions 32h and 1Fh in Chapter 6 for ideas on how to make it convenient to get the DPB of drives with removable media. Further, you won't want to do this for drives A: and B: in a system where these logical drives are mapped to the same physical floppy drive.

The version 4 DPB INT 21h Listing 8-7 differs substantially from that in the first edition of *Undocumented DOS*. A check is now used to deal with the above problem by checking for drives A: and B: in exactly the way that other versions, such as those created with DRIVER.SYS, may involve removable media. This earlier bogosity was further compounded by checking the floppy disk logical drive indicator at address 504h. Totally hopeless!

In 4.0, programs should use generic IOCTL calls to determine whether a device uses removable media (INT 21h, AX=4408h) and to get the logical drive map (INT 21h, AX=4409h). These calls, along with an INT 24h critical error handler invoked whenever there is no media in the drive at all, are incorporated into the get_dpb() function in the DPB.LIB version (DISKUTIL.C, Listing 8-4).

One last note about DOUPS. Many early DOS disk utilities were thrown into temporary confusion when the introduction of DOS 4.0 necessitated some fairly large changes to the DPB structure. The sectors per FAT field, for example, grew from a *byte* to a *word*, so all subsequent fields were suspect. Even worse, the location of the first data sector, used by CHKDSK, Function 32h and DOS's *PC Tech Journal* format, DISKCOPY, was modified in a manner applicable to the Norton Utilities and other software that relied on this undocumented DOS data structure. Rather than bemoaning necessary modifications, we chose to view this sort of change as a good excuse to hit up customers with an upgrade release.

Buffers and Disk Caches

Like any proper operating system, MS-DOS has *buffered* I/O. Rather than directly reading sectors off the disk, DOS first checks to see whether the sector is already present in an in-memory buffer. DOS uses a LRU (Least Recently Used) algorithm to determine which buffers to flush when it needs to read new data sectors. DOS buffers sectors, not higher-level clusters or even disk tracks. The BUFFERS statement in CONFIG.SYS controls the number of sector buffers available. A buffer is allocated to each recently used LRU. A pointer in List of Lists holds a pointer to the head of this list.

Each buffer starts with a 30-byte internal header which identifies the drive currently using that buffer, the sector to be held in the buffer, status bytes indicating what type of sector (FAT, directory, or data) is contained, and a pointer to the next buffer header in the chain.

The buffer chain is a point of debate in DOS 2.11. In DOS 1.x, there was a single sector buffer. Tim Paterson admitted this was "a decision made as expeditiously as possible." On the other hand, while DOS 1.x kept the FAT in memory, it did not keep any directory sectors in memory, in marked contrast to CP/M, which could require multiple disk reads just to find the location of a user's data. DOS 2.0 and higher rely entirely on the buffers for keeping often-used FAT sectors in memory. Paterson notes: "An Inside Look at MS-DOS." *Byte*, June 1983.

The new MS-DOS does not keep the file allocation tables in memory at all times. Instead, the tables share the use of the sector buffers. This means that at any one time all part or none of the FAT may be in memory. The buffer handling algorithms will presumably keep often-used sectors of directories and this applies to today's dual sectors of the FAT as well. This change in the DOS goes completely against my original design principles. Now, we're back to doing disk reads just to find out where the data is.

With today's average media, a memory resident FAT could occupy up to 128K (64K clusters * 16 bits) of memory.

DOS uses the buffers in sequence, changing the linkages as necessary to maintain the most recently used buffers near the front of the chain. An MS-DOS sector access first walks through the chain of headers, looking for the requested drive and sector. If found, it can use the buffer contents without having to hit the disk. Moving a recently used buffer up to the front of the chain guarantees that, when a search reaches the end of the chain without finding its sector, the buffer at the end would be the least recently used and, thus, the appropriate one for its contents to be replaced with the new data read from the disk.

Unfortunately, this simple approach did not take into account the pattern by which MS-DOS performs disk reads. In practice, the buffer chain filled rapidly with FAT and directory data, leaving only a few buffers for all the data transfers. The system was modified several times under DOS 2.0 and 3.0, but performance problems remained significant. The DOS buffers underwent a major implementation change in DOS 4.0, when IBM introduced a complicated hashing scheme and a mechanism for keeping buffers in expanded memory. This was thrown out in DOS 5.0, which returned to the simpler LRU buffers scheme.

If DOS 3.1 or later, DOS 5.0 and higher keep the buffers in the HMA. Also, for the first time in DOS 5.0, what is accessed with the INT 25h and INT 26h absolute disk read and write functions first check the sector buffers.

The Lookahead pointer points to the head of the buffers chain. SysVars in DOS 4.0 and higher also contains the *number* of buffers that is the value from the BUFFERS statement in CONFIG.SYS. For more details, see "SysVars or The List of Lists" later in this chapter. Determining BUFFERS= as programs the only practical way a program could use buffers information. This is difficult when running a program to determine what CONFIG.SYS file was used to boot the system. Under programs prior to the introduction of INT 21h function 5300h in DOS 4.0, one couldn't even tell what drive the system was booted from! So, we'll set up and a string manipulation program as might want to determine the value of BUFFERS= and FILES=, which we'll look at later.

To get the value of BUFFERS= in earlier versions of DOS, a program must walk the buffers chain, as shown in BUFFERS.C (Listing 8.8). In DOS 4.0 and higher, this program also prints out a description of each buffer's contents. For example:

```
C:\UNDOC2\CHAPB>buffers
FFFF:A8C8 -- C: #208 -- DIR
FFFF B968     C  #3133     DATA
FFFF A4A0     C  #7 -  FAT
FFFF 9A3C     C  #3226 -- DATA
FFFF B560     D  #109      FAT
FFFF B090     D  #110      FAT
,     etc  .
FFFF B11B -- A  #19     DIR
FFFF.9400 -- A  #20 -- DIR
BUFFERS=30
```

As you can see, the buffers may hold floppy diskettes as well as hard disks; however, network redirected drives are not allowed. It is instructive to run BUFFERS, then perform a disk operation such as DIR, or run some other program, and then run BUFFERS again. You can see the contents of the buffers change. Of course, running BUFFERS.EXE itself changes the contents of the buffers!

When DOS=HIGH, DOS usually allocates the buffers in the high memory area (HMA, just above the one megabyte mark). This area can be accessed only if the processor's A20 address line is enabled. If the buffers are in the HMA but A20 is off, BUFFERS.C in Listing 8.8 calls XMS to enable A20. This code is very similar to that XMS DOS itself uses when DOS=HIGH but A20 is off; see Chapter 6. Other programs in this chapter that access structures such as the CDS and SFT don't contain code to enable A20 because DOS 5+ late-load doesn't allocate these structures in the HMA. Some third-party products can move the CDS and SFT to upper memory (UMBs), but A20 is irrelevant to UMB access.

Few programs directly access the DOS buffers, and so moving them to the HMA "broke" few if any programs. In contrast, moving the CDS or SFT to the HMA might have disastrous results for programs that don't know to check A20 first. This might become important because Chicago is reported to have CONFIG.SYS settings such as LASTDRIVEHIGH and FILESHIGH, though these probably use UMBs rather than the HMA. On the other hand, A20 problems will be quite rare, because, as we saw in Chapter 6, XMS DOS leaves A20 on, and because any trivial DOS call will put A20 back on if some program turns it off.

Listing 8.8: BUFFERS.C

```
/*
BUFFERS.C    Display buffer chain, and count BUFFERS=
See also COUNTF.C to determine value of FILES=
Andrew Schulman, revised July 1993
Added code to check and enable A20 if BUFFERS are in HMA
*/

#include <stdlib.h>
#include <stdio.h>
#include <string.h>
#include <dos.h>

typedef unsigned char BYTE;
typedef unsigned short WORD;
typedef unsigned long DWORD;

#ifndef MK_FP
#define MK_FP(seg, ofs) \
    ((void far *) (((DWORD) (seg) << 16) | (ofs)))
#endif

#pragma pack(1)
    typedef struct dskbuf3 {
        struct dskbuf3 far *next;
        BYTE drive, flags,
        } DSKBUF3;

    typedef struct {
        WORD next, prev,
        BYTE drive, flags,
        DWORD sector,
        } DSKBUF4;
#pragma pack()

void fail(const char *s) { puts(s), exit(1); }

char *buff_status(BYTE flags)
{
    static char buf[128],
    buf[0] = '\0';
    if (flags & 2) strcpy(buf, "FAT ");
    if (flags & 4) strcat(buf, "DIR ");
    if (flags & 8) strcat(buf, "DATA ");
    if (flags & 16) strcat(buf, "REF ");    // referenced
    if (flags & 32) strcat(buf, "DIRTY ");  // modified, not yet written
    if (flags & 64) strcat(buf, "REMOTE ");
    return buf;
}
```

```
/* XMS stuff in case BUFFERS in HMA ********************************/
/* if XMS present, store entry point in xms_entrypoint */
static void (far *xms_entrypoint)(void) = (void (far*)()) 0;

int xms_is_present(void)
    {
    int available = 0;
    if (xms_entrypoint) return 1;

    _asm {
        mov     ax, 4300h
        int     2fh
        cmp     al, 80h
        je      present
        jmp     SHORT done
        }

present:
    available = 1,
    _asm {
        mov     ax, 4310h;
        int     2fh,
        push    ds,
        mov     ax, seg xms_entrypoint;
        mov     ds, ax;
        mov     word ptr xms_entrypoint, bx;
        mov     word ptr xms_entrypoint+2, es,
        pop     ds;
        }
done:
    return available;
    }

int xms_local_a20(int func)
{
    if (! xms_entrypoint)
        if (! xms_is_present())
            return 0;   // no XMS
    _asm mov ah, byte ptr func
    (*xms_entrypoint)(),
    // return value in AX; success=1
}

int xms_local_enable_a20(void)  { return xms_local_a20(5); }
int xms_local_disable_a20(void) { return xms_local_a20(6); }

static int testing = 0,
/*****************************************************************/

unsigned buffers(void)
{
    BYTE far *doslist,
    WORD buffers;

    _asm mov ah, 52h
    _asm int 21h
    _asm mov word ptr doslist+2, es
    _asm mov word ptr doslist, bx

    /* pointer to first disk buffer in List of Lists */
    if ( osmajor < 3)
        fatal("This program requires DOS 3.0 or higher");
    else if (_osmajor == 3)
    {
        DSKBUF3 far *dskbuf3,
        if ( osminor == 0)
            dskbuf3 = *((DSKBUF3 far * far *) (doslist + 0x13)),
        else
```

```
            dskbuf3 = *((DSKBUF3 far * far *) (doslist + 0x12));
        for (buffers=1, ; buffers++)
        {
            printf("buffer @ %Fp\n", dskbuf3);
            if ((dskbuf3 = dskbuf3->next) == (DSKBUF3 far *) -1L)
                break;
        }
    }
    else    // DOS 4, 5, 6
    {
        DSKBUF4 far *dskbuf4 = *((DSKBUF4 far * far *) (doslist + 0x12));
        WORD seg, first, in_use;

        if (_osmajor >= 5)  // DOS 5+ disk buffer info struct
            dskbuf4 = *((DSKBUF4 far * far *) dskbuf4);

        seg = FP_SEG(dskbuf4);
        first = FP_OFF(dskbuf4);
        in_use = 0;
// code added in case BUFFERS in HMA, have to check A20!
{
    DWORD lin = (DWORD) seg << 4L;
    lin += first;
    if (lin > 0x100000L)
    {
        DWORD far *low = (DWORD far *) 0x00000080L;
        DWORD far *high  = (DWORD far *) 0xFFFF0090L;
        puts("BUFFERS are HIGH");

        if (testing)
            xms_local_disable_a20();    // force A20 to test code below

        if ((low[0] == high[0]) && (low[1] == high[1]))
        {
            puts("A20 is off, turning A20 on");
#if 1
            if (! xms_local_enable_a20())
                fail("Can't enable A20");
#else
            // as we know from chapter 6, this will work too!!
            // in fact, we could just do this, and let DOS do all checking
            _asm mov ax, 3000h
            _asm int 21h
#endif
            if ((low[0] == high[0]) && (low[1] == high[1])) // still?
                fail("A20 still disabled!");
        }
    }
}

        for (buffers=1, ; buffers++)
        {
            if (dskbuf4->drive == 0xFF)
                printf("%Fp -- unused\n", dskbuf4);
            else
            {
                in_use++;
                printf("%Fp -- %c: #%lu -- %s\n",
                    dskbuf4,                        // pointer
                    'A' + dskbuf4->drive,           // drive
                    dskbuf4->sector,                // sector number
                    buff_status[dskbuf4->flags]);   // status
            }
            if (dskbuf4->next == first) // LRU list wraps around
```

```
            break;
        else
            dskbuf4 = (DSKBUF4 far *) MK_FP(seg, dskbuf4->next);
    }
    if (buffers != dostist[0x3F])   // number of buffers
        fail("Something wrong");
    printf("%u buffers in use\n", in_use);
    return buffers;
  }
}

main(int argc, char *argv[])
{
    WORD num_buf;
    if (argc > 1) testing++;    // any command line arg
    // To make program useful, stick various experiments in here
    // (e.g., call 21/0D to flush disk, read/write a file, etc.)
    num_buf = buffers();
    printf("BUFFERS=%d\n", num_buf);
    return num_buf;     // can check with ERRORLEVEL
}
```

For machines with sufficient memory, SmartDrive or another disk cache provides better performance than relying on the DOS buffers. When using SmartDrive, Microsoft rightly suggests using a setting of BUFFERS=1 (also). Whereas the DOS buffers cache DOS logical sectors from floppy diskettes as well as hard disks, SmartDrive works at the INT 13h level and only cares about hard disks. SmartDrive and other BIOS-level caches do not cache data from any devices that do not call down to INT 13h. This includes CD-ROM drives, for example, hence the growing popularity of CD-ROM "speed-up" products. As this book went to press, Microsoft announced that SmartDrive 4.2, which can cache CD-ROM drives, will be included with MS-DOS 6.2. SmartDrive 4.2 is also available separately from Microsoft's CompuServe forum.

After DOS 6.0 was introduced, many supposed DoubleSpace problems reported by *Inside Windows* actually turned out to be "cockpit errors" and user problems with using the newer SmartDrive, which introduced the "write-behind caching" that defers disk writes possibly for several seconds. The typical problem scenario is that a COPY is executed and appears to complete, the machine is turned off at the DOS C:\> prompt, and data is lost as soon as the user turns the machine off. If COPY's deferred writes haven't yet completed, very possibly the newer SmartDrive's aggressive caching—the end result is typically reported as "CHKDSK found lost clusters in file." Part of the problem was that users were not educated to check their hard drives' light before turning off the machine. As part of combatting these problems, SmartDrive 4.2 doesn't give back the DOS prompt until disk writes have completed.

For an excellent (though somewhat dated) discussion, see Scott Garrigus's "Untangling SmartDrive," *Dr. Dobb's Journal*, January 1992. Also see the brief discussion of "Undocumented SmartDrive" in Chapter 1. Some non-Microsoft disk caches also support the undocumented SmartDrive interface.

SysVars, or The List of Lists

Since the introduction of CONFIG.SYS with MS-DOS version 2.0, the DOS kernel has maintained a collection of pointers and variables near the start of its data segment. Since this collection of pointers is not officially documented, it's known by several names. The name in the DOS source code is SysInitVars, the structure is built by the DOS initialization code, called SysInit (see Chapter 6). This is often shortened to SysVars, which is the name used throughout this book. In the first edition, we referred to SysVars using the biblical sounding name, List of Lists.

SysVars, together with INT 21h AH=52h, which returns in ES:BX a pointer to this structure, is the central clearinghouse for virtually all of the undocumented data concerning the DOS file system. In addition, as already discussed in Chapter 7, SysVars provides the start of the Memory Control Block chain and the device driver chain. More than any other single structure, SysVars is the key to reaching the undocumented areas of DOS. The following is a schematic listing of just some of the structures that you can access directly or indirectly via SysVars. You can see why this is sometimes called the List of Lists!

```
Memory Control Block (MCB)
     Program Segment Prefix (PSP)
          Environment segment
          Job File Table (JFT)
Drive Parameter Block (DPB)
     File Allocation Table (FAT)
     Directory entries
System File Table (SFT)
Device driver chain
Disk buffers
Current Directory Structure (CDS)
FCB table
SHARE.EXE hooks
```

These structures are interconnected. For example, the SFT entry for block devices contains a pointer to the corresponding DPB, so does the CDS. One of the items contained in the DPB is a pointer to its corresponding device driver. Meanwhile, the heads of both the DPB and device chains are found directly in SysVars.

IO.SYS builds SysVars on the fly each time you boot your system. The starting point is the processing of CONFIG.SYS, which makes any installable device drivers part of the DOS kernel and possibly modifies certain values (for example, LASTDRIVE and the CDS pointer) stored in SysVars.

But what happens if no CONFIG.SYS file exists? Obviously no drivers are installed, but the default values that control the building of the SysVars are assembled into IO.SYS. Thus DOS sets FILES=8, LASTDRIVE=5, FCBS=4, calculates an appropriate BUFFERS= value from memory size and drive data, and sets the primary shell to C:\COMMAND.COM /P (assuming C: is the boot drive).

If CONFIG.SYS is processed, these commands will overwrite the default values. (Incidentally, Chicago appears to have new commands such as FILEHIGH= and LASTDRIVEHIGH=.) When DOS has parsed the entire file, with all commands executed or passed over with error messages, DOS builds SysVars from the values which then exist in the CONFIG control variables (see Chapter 7). It then discards the control variables along with the rest of the now surplus initialization code.

Incidentally, addition of the capability to load DOS high (into the High Memory Area) and to force device drivers and TSRs into Upper Memory Blocks has had some strange side effects on what happens during IO.SYS initialization. Before DOS 5.0 it was possible to predict just where in RAM each item processed from CONFIG.SYS would wind up. If high or upper memory is involved, however, you can't predict the memory map layout at all, because it depends on the availability of UMBs and the HMA, which, in turn, depend on the specific device drivers installed, such as HIMEM.SYS, EMM386.EXE, or 386MAX.SYS. That is, the addition of a single driver can now totally rearrange the locations in RAM at which all other drivers are loaded, moving some from high to low and others from low to high. For example, if CONFIG.SYS requested DOS=HIGH but an XMS server such as HIMEM.SYS was unavailable, you could end up with a rather strange memory map.

The Current Directory Structure (CDS)

SysVars contains a far pointer to an array of Current Directory Structures. Each drive in the system has its own CDS, which contains the current working directory and points to the DPB for that drive. This structure also contains attributes that specify whether the drive exists or not, whether it was modified by the JOIN or SUBST commands, or whether it is a network drive. Microsoft adopted the CDS as part of the networking additions begun in DOS 3.0 and plays a central role in maintaining foreign (not just network) file systems.

The CDS array contains one CDS for each possible block device or drive letter in the system. If you specify LASTDRIVE=Z, your system will have a 26-element CDS array, using the default value for LASTDRIVE. Your CDS may actually contain only two elements. In other words, the LASTDRIVE value is nothing more than the size of the CDS array. Each element in the array is 81 or 91 bytes long under DOS versions 3.0 - 6.0 (58h bytes for versions 4.0 and up). CURRDIR.H (Listing 8.9) includes a CDS structure that several different programs later in this chapter will use. As you can see, the CDS for each drive starts off with a 67 byte ASCIIZ string for the current path on the drive. It is from this that the CDS takes its name.

Listing 8.9: CURRDIR.H

```
/*
CURRDIR.H
Current Directory Structure (CDS), also Stacker and DoubleSpace stuff
Andrew Schulman, revised July 1993
*/

typedef unsigned char  BYTE;
typedef unsigned short WORD;
typedef unsigned long  DWORD;
typedef int            BOOL;

#include "diskstuf.h"    // for get_dpb(), DPB structure

#pragma pack(1)
typedef struct {
    BYTE current_path[67],  // current path                                  00h
    WORD flags,             // NETWORK, PHYSICAL, JOIN, SUBST, CDROM        43h
    DPB  far *dpb,          // pointer to Drive Parameter Block             45h
    union {
        struct {
            WORD start_cluster, // root  0000, never accessed= FFFFh        49h
            DWORD unknown,
            } LOCAL,        // if (cds[drive].flags & NETWORK)
        struct {
            DWORD redirifs_record_ptr,
            WORD parameter,
            } NET,          // if (cds[drive].flags & NETWORK)
        } u,
    WORD backslash_offset,  // offset in current path of "\"                4Fh
    // DOS4 fields for IFS
    // 7 extra bytes...
    } CDS;

// flags (CDS offset 43h)
#define NETWORK         (1 << 15)
#define PHYSICAL        (1 << 14)
#define JOIN            (1 << 13)
#define SUBST           (1 << 12)
#define REDIR_NOT_NET   (1 << 7)    // CDROM

CDS far *currdir(unsigned drive);

extern void fail(const char *s);    // app must define

/* Stacker    see IS_STACK.C */
typedef struct {
```

```
    WORD signature, version, ofs_tab,
    BYTE unknown[56], vol_num, unknown2[19];
    BYTE swap_str[4], drive_map[26],
    } STACKER_DRIVER;
#pragma pack()

STACKER_DRIVER far *stacker_detect(void),
int stacker_swapped(int drive),
DWORD stacker_drive(int drive, BOOL *pswap, BYTE *phost);

/* DoubleSpace -- see IS_DSPAC.C */
BOOL double_space_drive(BYTE drive, BOOL *pswap, BYTE *phost, int *pseg),
```

CURRDIR.H also contains function declarations and structures for testing Stacker and DoubleSpace drives, we examine these later on.

After reading through CONFIG.SYS and determining the value of LASTDRIVE=, DOS creates an array like the following through in DOS 4.0 and higher, each CDS element is 7 bytes larger:

```
CDS cds[LASTDRIVE],
```

Because LASTDRIVE fixes the size of the array, you normally can't expand the CDS without changing CONFIG.SYS and rebooting. The DOS kernel usually occupies the space immediately above the array that contains absolute pointers from many other parts of DOS. However, the program LASTDRIV.COM, shipped with QEMM, can increase LASTDRIVE on the fly and expands the CDS array. See XLASTDRV program in Chapter 2. Listing 2-18 shows how this is done.

Most programs, of course, do not create a CDS. Instead, you use the CDS already built by DOS. Rather than declare an array, you declare a far pointer to a CDS and set it using the CDS pointer at the appropriate offset in SysVars:

```
SysVars far *list;
CDS far *cds;
//
if (_osmajor == 2)                  fail("no CDS");          // DOS 2.0
if (_osmajor == 3 && _osminor == 0) cds = list->dos30_cds;   // DOS 3.0
else                                cds = list->dos31_cds;   // DOS 3.1+
```

To access the CDS for a given drive, you index into the array. However, because the size of a CDS entry is not known until run time, you can't restrict the program to running only under DOS 4.0 or higher. You must treat the CDS array not as an array of CDS entries but as an array of BYTEs:

```
BYTE far *cds;                      // rather than CDS far *
int drive,
int currdir_size = (_osmajor >= 4) ? 88 : 81;
//
if (drive >= lastdrive())           // see chapter 2 for lastdrive()
    fail("no such drive"),          // but watch out for Novell Netware
else
    printf("%Fs\n", &cds[drive * currdir_size]);
```

We've packaged this knowledge into a currdir() function that several programs will use later in this chapter. The function is called with the drive number, where drive A: is 0, and returns a far pointer to the CDS for that drive. Its implementation appears in CURRDIR.C, Listing 8-10.

Listing 8-10. CURRDIR.C

```
/*
CURRDIR.C
Current Directory Structure (CDS)
Andrew Schulman, revised July 1993
*/

#include <stdlib.h>
#include <dos.h>
```

```
#include "curdir.h"
typedef enum { UNKNOWN=-1, FALSE=0, TRUE=1 } OK;
/* return pointer to CDS for a given drive */
CDS far *curdir(unsigned drive)
{
    /* statics to preserve state: do one-time init */
    static BYTE far *dir = (BYTE far *) 0;
    static OK ok = UNKNOWN;
    static unsigned curdir_size;
    static BYTE lastdrv;
    if (ok == UNKNOWN)  /* do one-time init */
    {
        unsigned drv_ofs, lastdrv_ofs;
        /* curr dir struct not available in DOS 1.x or 2.x */
        if (! (ok = (_osmajor >= 3)))
            return (CDS far *) 0;
        /* compute offset of curr dir struct and LASTDRIVE in DOS
           list of lists, depending on DOS version */
        #define DOS(maj, min)   ((_osmajor == (maj)) && (_osminor == (min)))
        if (DOS(3,0))           { drv_ofs = 0x17; lastdrv_ofs = 0x1B; }
        else                    { drv_ofs = 0x16; lastdrv_ofs = 0x21; }
        _asm    push si     /* must preserve */
        /* get DOS list of lists into ES:BX */
        _asm    mov ah, 52h
        _asm    int 21h
        /* get LASTDRIVE byte */
        _asm    mov si, lastdrv_ofs
        _asm    mov ah, byte ptr es:[bx+si]
        _asm    mov lastdrv, ah
        /* get current directory structure */
        _asm    mov si, drv_ofs
        _asm    les bx, es:[bx+si]
        _asm    mov word ptr dir+2, es
        _asm    mov word ptr dir, bx
        _asm    pop si
        /* OS/2 DOS box sets dir to FFFF:FFFF */
        if (dir == (BYTE far *) -1L) ok = FALSE;
        /* compute curr directory structure size */
        curdir_size = (_osmajor >= 4) ? 0x58 : 0x51;
    }
    if ((ok == FALSE) || (drive >= lastdrv))
        return (CDS far *) 0;
    else   /* return array entry corresponding to drive */
        return (CDS far *) &dir[drive * curdir_size];
}
```

Like most of the LASTDRV programs in Chapter 2, curdir.c uses offsets computed at run time rather than C data structures set at compile time, because this seems better suited to the vagaries of undocumented DOS. The code assumes that DOS 5.0 and higher are fairly compatible with DOS 4.0. There are problems with this assumption, though, since while the DOS box in OS/2 1.10 presents itself to a program as DOS 10.10, in fact it more closely resembles DOS 3.x than DOS 4.x. The test for _osmajor >= 4 in the next-to-last line groups the OS/2 DOS box together with DOS 4.x instead of DOS 3.x. However, the DOS boxes in OS/2 1.x and 2.x don't provide a CDS anyway, and curdir anticipates this possibility by checking for the invalid -1L pointer FFFF:FFFF.

Contents of the CDS

So what's in the CDS that you would want to access it in the first place?

Offset zero from the start of each CDS entry holds a collection of bit flags indicating the type of drive and its status. As we saw in CURRDIR.ELF, these flags are NETWORK, PHYSICAL, JOIN, SUBST, and REDIR_NOT_NET (such as CD-ROM). For example, running SUBST C: C:\DOS2 marks the CDS entry for C: as SUBST flags & SUBST. Likewise, running JOIN A: C:\FLOPPY marks the CDS for A: as JOIN. Undefined drive flags will be zero, invalid.

How ASSIGN Works (It Does?)

The ASSIGN command (assertions in the first edition of this book notwithstanding) has *nothing* to do with the CDS. We probably just thought ASSIGN belonged in the same general category as SUBST and JOIN. It doesn't. Instead, ASSIGN.COM installs a small TSR that hooks all entry points to the DOS file system and contains a 26-byte lookup table. When the TSR is installed, all DOS file system functions use the ASSIGN table to change their drive codes from ones that the calling program specified to the ones contained in the table, as indexed by the caller's drive. For example, if ASSIGN A=C, then I would set the first slot in the table (A:) to 2 (C:). ASSIGN has an undocumented API call (INT 2Fh AX=0603h) that lets you access this table.

The DOS user's manual recommends using the SUBST command rather than ASSIGN. The command SUBST A: C:\ achieves exactly the same results as does ASSIGN A=C, but it goes through the CDS and has no side effects such as losing RAM to an unremovable TSR. The user manual also notes that Microsoft will continue to support SUBST, but makes no such promise with regard to ASSIGN.

Another word processor tip for Dos's APPEND, which tells you specify directories in which you can open files as if they were in the current directory. APPEND is intended to act somewhat like PATH, but for data files rather than executables. Like ASSIGN, APPEND has a little API (INT 2Fh AH=B7h). Also like ASSIGN, APPEND has nothing at all to do with the CDS and for the same reason we're mentioning it here: except that like ASSIGN (and also like FASTOPEN), it's a somewhat strange program supplied piece of MS-DOS that seems to do an end-run around MS-DOS.

If NETWORK flag is set, then the drive is controlled by the network redirector. The flag is not set for network drives mapped through CD-ROM drivers such as Microsoft CD-ROM Extensions. For the NETWORK flag to be set, the network software must support *DOS Interrupt 2Fh Function 1108h* (SET DRIVE NOT NETWORK) as MSCDEX uses to keep CD-ROM drives from being set to NETWORK. Unfortunately, most network software does not.

Why do the NETWORK flags matter? Because they're how we can tell if network drives show up in the CDS. Figuring out which drives belong to Novell NetWare proved tricky. NetWare version 4.0 doesn't appear in the CDS. NetWare versions 2.x and 3.x do. Even NetWare version 3.x and 4.x start *after* LASTDRIVE=Z: in CONFIG.SYS mysteriously appear in DOS. Because LASTDRIVE increases the size of the CDS, it's the first thing to look at when CDS values don't add up. The one important exception to our statement that the CDS is for DOS drives: Novell NetWare 2.x and 3.x use the CDS because, until NetWare 4, it provided a convenient way to store the IPX.COM 2Fh number rather than with the redirector. Novell stopped using DOS for networking with NetWare 2.x, but it still uses the redirector and CDS. Starting with version 4.0, NetWare uses its own network redirector, which is described in detail later in this chapter—and therefore NetWare 4 drives do show up in the CDS.

Offset 43h from the start of the CDS entry holds a far pointer to the drive's DPB (cds[drive].dpb). Since the DPB in turn contains a far pointer to the actual device driver, this links the logical drive to the physical drive. Earlier in this chapter we noted that get_dpb() drives hits the disk, whereas cds() drives don't. On the other hand, for removable media, which is where hitting the disk is a major problem in the first place, cds().drive.dpb may hold stale data.

For local drives (that is, where cds[drive].flags & NETWORK == 0), offset 49h in the CDS contains the starting cluster for the current directory (cds[drive].DOS_start_cluster). DOS, of course, has its own uses for this, but other programs could use this for a different purpose to implement the earlier NAMED_FUNC program, such a string S to a directory, with all having to traverse the directory structure, just to find the cluster number. Such a program could CD to a directory and pull the cluster out of CDS, letting DOS do all the hard work. You will see later that the SET_sublark contains the starting cluster for open files.

The first character (offset 0) in each drive's CDS is the current path (cds.drive.current_path), but it isn't always what you might expect. The current path in the CDS tells you where the data really is, rather than a drive's address. You can see this in the output from a utility named ENUMDRV, the source code for which you will see shortly.

```
C:\UNDOC2>\dos\join a: c:\floppy

C:\UNDOC2>subst g: c:\undoc2

C:\UNDOC2>rem e: and f: are network drives

C:\UNDOC2>phantom -5512 h:

C:\UNDOC2>enumdrv
A   C:\FLOPPY                          JOIN [ROOT]
B   B:\                                [NOT_ACC]
C   C:\UNDOC2                          [#18] STACKER (swapped D:)
D   D:\UNDOC2                          [#26348]
E   \\BIN\EXPORT\DOS                   NETWORK
F   \\HOME\U\ANDREW                    NETWORK
G   C:\UNDOC2                          SUBST [NOT_ACC] STACKER
H   Phantom H:\                        NETWORK
```

Here COMMAND.COM prompts show we were logged into drive C at the \UNDOC2 cds directory. This shows up correctly in the CDS for drive C. The SUBST command permits us to address future cds drives as if they were other, nonexistent CDS entries (drive G). The situation is reversed when we use JOIN to refer to an entire drive as though it were a subdirectory on another drive (see the CDS for drive A above). The first byte in the current path string contains the drive letter of the SUBST or JOIN target.

As you can see from drives E and F in the ENUMDRV map above, network drives are treated differently from local drives. Attaching a drive to a network file server means that all references to the drive actually refer to the server, which is generally thought of and is addressed with a two-leading-"\" string. Here's an example. The protocol part of this so-called Universal Naming Convention (UNC) that Microsoft uses in different networking products such as PC LAN Program Manager and Windows for Workgroups. Here, using PC-NFS from Sun's PC-NFS software, drives E and F were mapped to different directories on a Sun SPARCstation running SunOS. This is a good illustration of how the DOS file system allows installable file systems. You can use the disk of a UNIX RISC machine as though it were part of DOS.

The word at offset 45h in the CDS.cds.drive_backslash_offset contains the number of characters in the pathname that precede the root directory indicator. This is often manually set to a value of 2 to skip the drive letter and colon when a SUBST command is processed. The value changes to skip over the drive letter and all DOS directory names concealed by SUBST. That's why SUBST C: C:\UNDOS creates the string C:\UNDOS rather than C:. A current path string copies the start cluster and DPB pointers from drive C and sets the SUBST bit in the drive C: status word. It sets the directory

cluster number to that for the first sector of the C:\DOS directory on drive C: and sets the word at 43h to a value of 4. the number of characters preceding the final \ of the pathspec string.

The CDS may store the short DOS name of an alien file system such as C:\NEWPORT\DOS or C:\DOS\FILE~ANDREW in the ENUMDRV output above. Mixed drive:\backslash offset can also block out such names. The Phantom sample program later in this chapter uses this; see the ENUMDRV output. But this is possibly not normal behavior for a network redirector. An engineer at Novell, whose NetWare DOS does not appear to support this behavior, has told us that no other network redirector uses the CDS in quite this way. Perhaps Phantom should instead use UNC naming.

As you navigate the directory tree, the path string stored in the CDS tracks your position so that DOS can always convert your relative path references (those which do not begin with a backslash) into fully canonical path names. When you change directories by calling INT 21h function 3Bh or its user-level counterpart, the CD command, DOS updates only the drive's current path.

Conversely, changing a CDS drive's current path actually changes the current directory. Going into your favorite debugger, locating the CDS for the current drive, and manually editing the path string in the CDS is sufficient to change directories. The change is immediately reflected in the PROMPT PG display, for example. It's now quite clear why this is called the Current Directory Structure.

However, there is one problem with the CDS array. There's only one. All DOS tasks share the single CDS. The reader who thinks of DOS as a single-tasking operating system might well ask, "What DOS tasks?" If DOS runs only one task, as of course there is only one CDS." But as shown in Chapter 1's discussion of PSPs and in Chapter 9's discussion of SFTs and DOS multitasking, this just isn't so. Under especially the extended of Windows Enhanced mode, where multiple DOS boxes can be preemptively multitasked, care in manipulating the DOS current directory at the same time. Windows uses its own data to maintain a separate CDS for each DOS box; see Chapter 11. Furthermore, each Windows program has its own current drive and directory, maintained in its Task Database (see *Undocumented Windows*, Chapter 5).

Walking the CDS Array

The curdir_test function in Listing 8-10 goes to some trouble to ensure that it can be called frequently without any duplicated effort. However, curdir() can be called in a loop for each drive in the system, producing the ENUMDRV output shown earlier. Listing 8-11 shows ENUMDRV.C, which contains the actual loop, along with some other code we'll get to in a moment.

Listing 8-11: ENUMDRV.C

```
/*
ENUMDRV.C -- uses curedir() in CURRDIR.C
Added CD ROM bit, DoubleSpace test, Stacker test, primitive RAM disk test
Andrew Schulman, revised July 1993

bcc enumdrv.c currdir.c is_stack.c is_dspac.c diskstuf.c
*/

#include <stdlib.h>
#include <stdio.h>
#include <string.h>
#include <dos.h>

#include "currdir.h"     // includes DoubleSpace, Stacker too
#include "diskstuf.h"    // get_dpb

void fail(const char *s) { puts(s); exit(1); }

int maybe_ram_disk(int drive);

main()
{
    CDS far *dir;
    BYTE host;
    BOOL swapped,
```

```
    unsigned lastdrv;
    int i, seq;

    _dos_setdrive(0xFF, &lastdrv);
    for (i=0, i<lastdrv, i++)
    {
        if (! (dir = currdir(i)))
            fail( can't get current directory structure");
        else if (dir->flags)    /* is this a valid drive? */
        {
            printf( %c   %-40Fs   ", 'A' + i, dir->current_path),

            if (dir->flags & JOIN) printf("JOIN "),
            if (dir->flags & SUBST) printf("SUBST "),
            if (dir->flags & REDIR_NOT_NET) printf("REDIR_NOT_NET "),

            if (dir->flags & NETWORK) printf("NETWORK ");
            else switch (dir->u.LOCAL.start_cluster)
            {
                case 0:      printf("[ROOT] "); break;      // root dir
                case 0xFFFF  printf( [NOT_ACC]  ), break,   // not accessed
                default      printf("[#%u]  , dir->u.LOCAL start_cluster),
            }   // check cluster numbers by running CLUSTNAM

            if (double_space_drive(i, &swapped, &host, &seq))
                printf( DBLSPACE %c:\\dblspace.%03u", 'A' + host, seq),

            if (stacker_drive(i, &swapped, &host))
            {
                printf( STACKER"),
                if (swapped) printf(" (swapped %c:)", 'A' + host),
            }

            if (maybe_ram_disk(i)) printf("RAM disk?"),

            putchar('\n'),
        }
    }
    return 0,
}

int maybe_ram_disk(int drive)
{
#ifdef USE_DOS_DPB
    return (currdir(drive)->dpb->copies_fat == 1);
#else
    DPB far *dpb = get_dpb(drive+1),
    return (dpb) ? (dpb->copies_fat == 1) : 0,
#endif
}
```

For each drive FANTDRIVE ENUMDRV calls the currdir function and prints out values from the CDS: but's the current path string, the drive type, and for local drives, the starting cluster of the current directory. ENUMDRV then calls some additional functions to check for DoubleSpace and Stacker compressed drives and for RAM disks. We'll get to the DoubleSpace and Stacker code in a moment.

Detecting RAM Disks

The tiny maybe_ram_disk function is interesting. Since RAM disks are intended to look as much like physical disks as possible, there's no sure test for a RAM disk. However, RAM disks generally provide only one FAT, and the presence of a single FAT is a common test for a likely RAM disk. As noted earlier, for floppy and hard disks DOS forces the DPB to indicate two FATs, no matter what the BPB says.

The number of FATs is retrieved from the DPB (note that network drives don't have DPBs). The maybe_real_disk function can get the DPB either from the CDS curr_dir->drive->dpb or by calling the get_dpb function from DISKUTIL.C (Listing 8.4). This involves the usual trade-off between hitting the disk with get_dpb() and possibly getting a stale DPB with curr_dir->drive->dpb. Hitting the disk with get_dpb() isn't so bad because this function checks for removable media and contains a critical error handler.

For an alternative approach to drive enumeration, see the DRVINFO program in Chappell's *DOS Internals*.

DoubleSpace Drives

DoubleSpace is an on-the-fly disk compression subsystem that Microsoft licensed from Vertisoft, makers of the earlier DoubleDisk product, and incorporated in MS-DOS 6.0. ENUMDRV checks for DoubleSpace drives by calling the double_space_drive function from IS_DSPAC.C, shown in Listing 8.12.

Listing 8.12. IS_DSPAC.C

```
/*
IS_DSPAC.C -- Is this a DoubleSpace drive?
Based on DRVINFO.C from Microsoft's DSDUMP sample code (March 1993)
Andrew Schulman, July 1993
NOTE:  *None* of this is undocumented!
*/

#include <stdlib.h>
#include <stdio.h>
#include <dos.h>
#include "curdir.h"

BOOL DSGetDriveMapping(int drive, BOOL *pcomp, int *phost, WORD *pseq)
{
    BYTE ldata, hdata;
     _asm mov ax, 4A11h      /* DBLSPACE.INT 2Fh function */
    _asm mov bx, 1           /* DSGetDriveMapping */
    _asm mov dl, byte ptr drive
     _asm int 2fh
    _asm or ax, ax
    _asm jnz no_dblspace
    _asm mov byte ptr ldata, bl
    _asm mov byte ptr hdata, bh
    *pcomp   = ldata & 0x80,  /* compressed drive flag */
    *phost   = ldata & 0x7F,  /* host drive (if drive compressed) */
    *pseq    = hdata,         /* compressed drv sequence # (0..254) */
    return 1;
no_dblspace:
    return 0;
}

// Can generate CVF filename with host \DBLSPACE.seq
BOOL double_space_drive(BYTE drive, BOOL *pswap, BYTE *phost, int *pseq)
{
    WORD seq, seq2;
    int drHost, drHost2;
    BOOL fCompressed, fSwapped;

    if (! DSGetDriveMapping(drive, &fCompressed, &drHost, &seq))
        return 0;
    if (! fCompressed)
        return 0,   /* could be host drive, but don't care */

    fSwapped = 0;
    if (DSGetDriveMapping(drHost, &fCompressed, &drHost2, &seq2))
        if (drHost2 == drive) // host of host is drive itself: means swapped
            fSwapped = 1;
```

```
    *phost = drHost;
    *pswap = fSwapped;
    *pseq = seq;
    return 1;
}
```

If double space drive returns TRUE indicating the specified drive is compressed with DoubleSpace this function also passes back the host drive sequence number and a BOOL indicating whether the DoubleSpace drive was swapped with its host. Taking INC MDRV snapshots before and after creating a DoubleSpace drive makes clearer what all this means

```
C:\DOS6>\undoc2\chap8\enumdrv
A   A:\                                         [ROOT]
B   B:\                                         [NOT_ACC]
C   C:\DOS6                                     [#27112]

C:\DOS6>dblspace a: /mount
DoubleSpace is mounting drive A:
DoubleSpace has mounted drive A:

C:\DOS6>\undoc2\chap8\enumdrv
A   A:\                                         [ROOT] DBLSPACE I $ I:\dblspace.000
B   B:\                                         [NOT_ACC]
C   C:\DOS6                                     [#27112]
I   I:\                                         [ROOT]
```

You can see that DBLSPACE /MOUNT created a new drive I and exchanged the nature of drive A: Drive I is the old drive A: and drive A: is just a DoubleSpace file I:\DBLSPACE.000 that DoubleSpace arranges to look like a larger drive A: Drives A: and I: have been swapped. In other words before using DBLSPACE /MOUNT drive A: contained the hidden system file A:\DBLSPACE.000 while now it appears on drive I:

Deleting DBLSPACE.000 in turn deletes DBLSPACE.BIN creates a DoubleSpace drive called a Compressed Volume File (CVF). The CVF contains all the compressed data that the user thinks of as belonging to the drive. It also contains all the internal DoubleSpace data structures such as the MDFBPB the FAT the CVFHEAD and MDFAT. MDF stands for Magic Disk which was the original internal name for DoubleSpace.

Microsoft documents the CVF file format and these structures in a "DoubleSpace Compressed Volume File Overview" in the MS-DOS 6.0 *Programmer's Reference* and in sample code including a CVFHEAD header file as part of the Microsoft Driver Source and on the Microsoft Developer Network (MSDN) CD-ROM. There is also a useful introduction to DoubleSpace internals in the article "Inside MS-DOS 6.0" by Ron Slaska Eric Strauss and Richard Freedman in *Byte* July 1993. Unfortunately the article fails to point out the work done on DoubleSpace by its creators at Vertisoft.

INT 2FH AX=4A11H BX=1 (DblSpaceDriveMapping INT 2FH AX=4A11H BX=1) is the DoubleSpace programming interface documented in Microsoft's "DoubleSpace System API Specification" Version 1.00(1) of this specification dated March 12 1993 includes structures 3 and 4 (DSDriveInfo and DSDriveParms) that were previously reserved for use by SmartDrive. This leaves two undocumented calls BX=FFFFh and BX=FFFEh that DBLSPACE.SYS /MOVE uses to relocate DBLSPACE.BIN to its final location in memory prior to the DOS 6.0 Payload API that DoubleSpace uses (see Chapter 1).

What is lost in the DoubleSpace is fairly well documented it's also fortunate that most applications won't notice the differences in the first place. After all the point of on-the-fly disk compression is to operate on files transparently. DoubleSpace makes all normal DOS file system structures appear as if files existed on the DoubleSpace drive even though they are in fact just data in a DBLSPACE.xxx file simulated outright by DBLSPACE.BIN.

However, some utilities need to know about the actual DoubleSpace structures such as the MDFAT and MDPB. For example, Norton Utilities 7.0 includes versions of the Norton Disk Doctor (NDD) and Speed Disk that can repair and defragment DoubleSpace and Stacker drives (presumably in a future version). Microsoft's DBLSPACE /CHKDSK or Stac Electronics' SCHKDSK utilities can

If you plan to work on DoubleSpace information, consider writing a program to compute the compression ratio for a file, as DIR /C does in DOS 6.0:

```
 Volume in drive A is DOS6
 Volume Serial Number is 1603-265C
 Directory of A:\

COMMAND  COM     52925 03-10-93   6:00a   1.4 to 1.0
README   TXT       350 07-12-93   3:11p  16.0 to 1.0
CHAP8    ZIP    103029 07-16-93   6:13p   1.0 to 1.0
CHAP8C   ZIP     58469 07-16-93   2:12p   1.8 to 1.0
DR       ZIP     24075 07-10-93  10:27a   1.0 to 1.0
...
FAT      EXE      8270 07-10-93   9:26p   2.5 to 1.0
DPBTEST  EXE      8354 07-15-93  12:18p   2.5 to 1.0
                  1.7 to 1.0 average compression ratio
      49 file(s)     550393 bytes
                    1384448 bytes free
```

How does DIR /C know that CHAP8.ZIP has 1.0 compression, whereas DPBTEST.EXE has 2.5? Certainly the information doesn't come from any of the standard DOS file system structures. Instead, it comes from the MDFAT. Whereas non-compressed DOS disks have a fixed formula for translating cluster numbers to sector numbers (see CLUSTER_TO_LSN in Listing 8-5), DoubleSpace uses a table to find the number of sectors per cluster, depending on the possible compression. Now, instead of a simple shift-to-sectors formula, DoubleSpace uses the MDFAT, which is a bit more complicated. Consider. MDFAT is a very poor name for the structure given that it was not a FAT at all. (Even though the FAT is sometimes called CLUSTMAP or SECTMAP.) For each cluster, the MDFAT contains a four-byte entry, shown in the following C structure with bit-field declarations (Microsoft's CVF.H header file). Note that Borland C++ does not accept the unsigned int bit fields; in practice, you should access the MDFAT fields with shifts and masks, as in Listing 8-13.

```
typedef struct {
    unsigned long secStart   :21,     // starting sector for cluster
    unsigned reserved : 1;
    unsigned cCmp    : 4;             // # of compressed sectors
    unsigned cUnc    : 4;             // # of uncompressed (original) sectors
    unsigned fUsed   : 2;             // Is entry in use? data compressed?
    } MDFAT_ENTRY;

MDFAT_ENTRY MDFAT[num_clusters];
```

Because 4 bits each are devoted to the count of original sectors (cUnc) and the count of possibly compressed sectors found in the CVF (cCmp), there are a maximum of 16 sectors per cluster. Given a cluster whose original uncompressed size is 16 sectors (cUnc == 16), the compressed cluster occupies less than 16 sectors (cCmp < 16). With 2:1 compression, cCmp == 8. With no compression (for example, a portion of CHAP8.ZIP), cCmp == 16.

Data can't be stored in partial sectors, of course. With a *maximum* of 16 sectors per cluster and 512 bytes per sector, a DoubleSpace cluster can hold a maximum of 512 megabytes of *uncompressed* data.

The cUnc field in the MDFAT entry is important. DoubleSpace does not assume a fixed 16 uncompressed sectors per cluster; it uses cUnc to record the maximum. Files whose true size is not a multiple of 16 sectors will have a smaller MDFAT entry whose cUnc field is less than 16. In this way, DoubleSpace changes the space-wasting cluster overhang of hard disks under DOS to a much less wasteful sector overhang.

You can see this clearly in the following session using two of our earlier programs, NAMCLUST (see Listing 8-3) and FAT (see Listing 8-2), as well as a Microsoft DoubleSpace dumper called appropriately enough DSDUMP. Microsoft provides the C source code for DSDUMP along with the DoubleSpace documentation on its CompuServe forum.

```
C:\UNDOC2>namclust a:\command.com
A:\COMMAND.COM ==> 12 (sect 256, 0x00000100)

C:\UNDOC2>fat a: 12
12-18 (7)

7 clusters in 1 groups

C:\UNDOC2>dsdump a: /#14-20
DoubleSpace File Dumper - Version 0.58

Drive: A (mounted from 1 \DBLSPACE.000)

MDFAT entries 14 to 20
Flags  A=Allocated, F=Free, C=Compressed, U=Uncompressed
-------------------------------------------------------

FAT#  MDFAT# Flags cUnc cCmp secStart
----- ----- ----- ---- ---- --------
   12     14   A,C   16   13      261
   13     15   A,C   16   14      274
   14     16   A,C   16   15      288
   15     17   A,C   16   14      303
   16     18   A,C   16   12      317
   17     19   A,C   16   10      329
   18     20   A,C    8    1      339
```

This shows where DIR /C gets those compression ratios. For COMMAND.COM, recall that DIR /C showed compression of 1.4 to 1.0. Adding up the cUnc column, we get 16+16+8 = 104 sectors for the original COMMAND.COM. Adding up the cCmp column, we get 13+14+15+14+12+10+1 = 79 sectors used in DBLSPACE.000. Dividing 104 by 79, we get 1.31.

But if the actual compression ratio is 1.31, why does DIR /C get 1.4? Because, rather than add up the actual cUnc sector counts for the file, taking into the account the final count that is generally less than 16 (for FAT #18, it was 8), DIR /C instead simply multiplies the number of clusters by 16:

```
compression ratio = (num_clusters * 16) / total cCmp
```

This formula explains why DIR /C shows 1.00 to 1.0 compression ratios for all files whose size is less than 512 bytes. Stacker's SDIR shows similarly inflated compression ratios for small files. With DIR /C, even a 1-byte file shows a compression ratio of 16.00 to 1.0. It's been squeezed down to 1/16 of a byte—this is mathematically bogus at best, but in fact it's only mostly bogus. As we pointed out earlier, a file whose size is less than 512 bytes at least occupies the full cluster size on an uncompressed disk. By comparing the number of clusters with the sectors per cluster, DIR /C reflects the fact that DoubleSpace eliminates cluster overflow. A supposedly one-byte file would in fact occupy a total cluster chain DoubleSpace could store only one byte for in a single sector.

The only problem is that DIR /C assumes 16 sectors per cluster, which is appropriate for the DoubleSpace drive, but probably not appropriate for the original uncompressed media. As pointed out earlier, high-density floppies generally use 1 sector per cluster, and hard disks generally use 4 or 8 sectors per cluster. Thus, a more accurate estimate of true compression ratios is 1.1 for a floppy (1 sector/cluster) and 4.1 or 8.1 for a hard disk. A word to the wise: 16:1 for most media with 16 sectors per cluster. More accurate compression ratios require reading a file's last cluster, using the sectors per cluster from the DPB of the original uncompressed host:

```
((num_clust - 1) * 16) + original sect_per_clust) / total cCmp
```

DIR /C uses a similar formula, producing more accurate compression ratios.

```
                    bytes          /C ratio        /CH ratio
COMMAND  COM        52925          1.4             1.3
ENUMDRV  EXE        9252           2.1             1.3
READTHIS TXT        350            16.0            1.0
DM       ZIP        24075          1.0             1.0
DSDUMP   ZIP        13956          1.0             1.0
CHAPB    ZIP        103029         1.0             1.0
CHAPBC   ZIP        58469          1.1             1.0
FILES    C          7949           1.8             1.8
DPBTEST  C          1957           5.3             1.3
FAT      EXE        8270           2.5             1.5
DPBTEST  EXE        8354           2.5             1.5

Average compression ratio          1.4             1.1
```

In this example, COMMAND.COM was located on a high-density floppy with one sector per cluster, so the original FAT compression ratio was accurate. The true compression ratio—that is, the effect of DoubleSpace on the original media—for a tiny file like README.TXT is not 16:1 but instead depends on the original media. For hard disks it is 8:1 or 4:1; for high-density floppies it is only 1:1.

There is still a problem because, at least in the original release of DoubleSpace, the number of compressed sectors can in some cases exceed the original number of uncompressed sectors on the host media (that is, cUnc > cComp). For example:

```
C:\UNDOC2>namelust f:\dsdump.zip
A:\DSDUMP.ZIP ==> 5 (sect 36, 0x00000024)

C:\UNDOC2>fat f: 5
5->32 (28)

28 clusters in 1 groups

C:\UNDOC2>namelust a:\dsdump.zip
A:\DSDUMP.ZIP ==> 32 (sect 556, 0x0000022c)

C:\UNDOC2>fat a: 32
32->33 (2)

2 clusters in 1 groups

C:\UNDOC2>dsdump a: /R34-35
DoubleSpace File Dumper - Version 0.58

Drive A: (mounted from I:\DBLSPACE.000)

MDFAT entries 34 to 35
Flags: A=Allocated, F=Free, C=Compressed, U=Uncompressed
-------------------------------------------------------

FAT#  MDFAT#  Flags  cUnc  cComp  secStart

  32     34    A,U    16    16       454
  33     35    A,U    12    16       470
```

In other words, the original occupied 28 one-sector clusters and the "compressed" version occupies two 16-sector clusters, so the compression ratio is 28 to 32, or 0.875 to 1.0. Both DIR /C and DIR /CH report a 1.1 compression. However, the problem here is a faulty compression algorithm. As the FAT flags above show, DoubleSpace has decided it can't compress this data, so it is stored uncompressed. It is not clear why DoubleSpace should bother storing 16 sectors when the original has only 12. One description has that this is just a bug that is being fixed, and that we're making too big a deal of it here.

In any case, Microsoft's DSDUMP shows that you can derive compression ratios (whether true compression ratios or the inflated ones DIR /C produces) by examining the MDFAT entries in the CVF.

How then does a program find the MDFAT for a DoubleSpace drive? First call the DoubleSpace DSGetDriveMapping API function (INT 2Fh AX 4A11h BX 0) to find the host MDBLSPACE.xxx CVF file name (as shown by the double space drive function in DSPACE Listing 8-12). Next open the CVF file and read in the MDBPB to find the MDFAT. The MDBPB is an extended BPB at the start of the CVF file and includes a secMDFATStart field.

The setup program in Listing 8-13, when run with a /VERBOSE command-line switch, dumps the entire MDFAT entries from a CVF file (to stdout). This program is not terribly useful on its own, but you could layer it together with NAMELIST.BAT and DSPACE to produce a program to show accurate compression ratios for any DoubleSpaced file. Use the code from NAMELIST to turn a filename into a starting cluster, use the FAT code to find the file's entire set of clusters, use DSPACE to locate the CVF file on the host drive, and then use the code in Listing 8-13 to examine the MDFAT entries for the file's clusters.

Listing 8-13. MDFAT.C

```
/*
MDFAT.C -- Dump a DoubleSpace MDFAT
Based on Microsoft's DSDUMP sample code
Andrew Schulman, July 1993
NOTE:  "NONE" of this is documented!
cl mdfat.c ts_dspac.c
*/

#include <stdlib.h>
#include <stdio.h>
#include <string.h>
#include <ctype.h>
#include <dos.h>

typedef unsigned char  BYTE;
typedef unsigned short WORD;
typedef unsigned long  DWORD;
typedef int            BOOL;

#pragma pack(1)
typedef struct {
    BYTE    jmpBOOT[3];     // Jump to bootstrap routine
    char    achOEMName[8];  // OEM Name ("MSDSP6.0")
    // MS-DOS BPB
    WORD    cbPerSec;
    BYTE    csecPerClu;
    WORD    csecReserved;
    BYTE    cFATs;
    WORD    cRootDirEntries, csecTotalWORD;
    BYTE    bMedia;
    WORD    csecFAT, csecPerTrack, cHeads;
    DWORD   csecHidden, csecTotalDWORD;
    // DoubleSpace extensions
    WORD    secMDFATStart;
    BYTE    mLog2cbPerSec;
    WORD    csecMDReserved, secRootDirStart, secHeapStart, cluFirstData;
    BYTE    cpageFAT;
    WORD    RESERVED1;
    BYTE    mLog2csecPerClu;
    WORD    RESERVED2;
    DWORD   RESERVED3, RESERVED4;
    BYTE    f12BitFAT;
    WORD    cmbCVFMax;
    } MDBPB;
#pragma pack()

void fail(const char *s) { puts(s); exit(1); }

// my buffer size
```

```
#define MDFAT_PER_BLOCK     (2048)
#define MDFAT_BLOCK_SIZE    (MDFAT_PER_BLOCK * sizeof(DWORD))

// handy macros from Microsoft's DSDUMP.C
#define GET_SECSTART(dw)    ((dw) & 0x3FFFFFL)
#define GET_CSEC_CODED(dw)  (1 + (int) (15 & ((dw) >> 22)))
#define GET_CSEC_PLAIN(dw)  (1 + (int) (15 & ((dw) >> 26)))
#define GET_FLAGS(dw)       (3 & ((dw) >> 30))
#define USED(dw)            (GET_FLAGS(dw) & 2)
#define UNCOMPRESSED(dw)    (GET_FLAGS(dw) & 1)

static DWORD sectors_coded   0, sectors_plain = 0;
static WORD clusters_in_use = 0,
static WORD first_data_clust = 0;
static int verbose = 0, did_banner = 0;

void do_mdfat_entry(WORD cluster, DWORD mdfat_entry)
{
    int coded, plain;

    if (USED(mdfat_entry)) clusters_in_use++;
    else                   return,

    sectors_coded += (coded = GET_CSEC_CODED(mdfat_entry)),
    sectors_plain += (plain   GET_CSEC_PLAIN(mdfat_entry)),

    if (verbose || ( coded > plain))
    {
        if (! did_banner,
        {
            if (coded > plain)
                printf("Expanded clusters (cCmp > cUnc):\n"),
            printf("Cluster    Sector cCmp cUnc C/U\n");
            printf(                                  \n ),
            did_banner++,
        }
        printf(  %u    %8lu   %2u   %2u   %c\n ,
            cluster - first_data_clust,
            GET_SECSTART(mdfat_entry),
            coded, plain,
            UNCOMPRESSED(mdfat_entry) ? 'U' : 'C');
    }
}

main(int argc, char *argv[])
{
    char *cvf_name,
    FILE *cvf;
    MDBPB *mdbpb;
    DWORD *mdfat_block, num_sect, mdfat_bytes,
    WORD num_clust, mdfat_blocks, ratio, >, ];

    if (argc < 2 || argv[1][1] == '?')
        fatal  usage  mdfat [DoubleSpace drive or CVF file]"),
    if (strcmp(strupr(argv[1]), "-VERBOSE") == 0)
        { verbose++; argv++; argc--, }
    cvf_name = argv[1];

    if ((cvf = fopen(cvf_name, "rb")) == NULL)
    {
        // If we can't open the specified filename, maybe it's not
        // a filename at all   See if maybe it's a DoubleSpace drive
        // letter   If so, use function from IS_DSPAC C to get CVF name
        extern BOOL double_space_drive(BYTE drive, BOOL *pswap,
            BYTE *phost, int *pseq),
        BYTE drive = (BYTE) (toupper(cvf_name[0])   'A'),
        BYTE swap, host;
        int seq,
```

```
    if (doub.e_space_drive(drive, &swap, &host, &seq))
    {
        static char filename[16];
        sprintf(filename, "%c \\dblspace.%03u", 'A' + host, seq),
        printf("CVF file: %s\n", filename);
        cvf_name = filename,
        if ((cvf = fopen(cvf_name, "rb")) == NULL)
            fail("can't open CVF file"),
    }
    else
        fail("can't open CVF file");
}
if (! (mdbpb = malloc(sizeof(MDBPB))))      fail("insufficient memory"),
if (! fread(mdbpb, sizeof(MDBPB), 1, cvf))  fail("can't read MDBPB"),
if (! (mdbpb->jmpBOOT[0] == 0xE9) || (mdbpb->jmpBOOT[0] == 0xEB)))
    fail("not a valid CVF file"),   // has to start with JMP

first_data_clust   mdbpb->cluFirstData, // used by do_mdfat_entry()
num_sect = (mdbpb->csecTotalWORD) ?
    mdbpb->csecTotal.WORD   mdbpb->csecTotalDWORD,
num_clust   1 + (num_sect / mdbpb->csecPerClu),
mdfat_bytes = (DWORD) num_clust * sizeof(DWORD),
mdfat_blocks = 1 + (mdfat_bytes / MDFAT_BLOCK_SIZE),

if (! (mdfat_block = (DWORD *) malloc(MDFAT_BLOCK_SIZE)))
    fail("insufficient memory");

fseek(cvf, (1 + mdbpb->secMDFATStart) * mdbpb->cbPerSec, SEEK_SET),
for (i=0; i<mdfat_blocks-1; i++)
    if (fread(mdfat_block, MDFAT_PER_BLOCK, sizeof(DWORD), cvf))
        for (j=0; j<MDFAT_PER_BLOCK; j++)
            do_mdfat_entry((i*MDFAT_PER_BLOCK)+j, mdfat_block[j] ,
    else
        fail("can't read MDFAT");

if (fread(mdfat_block, MDFAT_PER_BLOCK, sizeof(DWORD), cvf)  // last one
    for (j=0, j<(num_clust % MDFAT_PER_BLOCK), j++)
        do_mdfat_entry((mdfat_blocks-1) * j, mdfat_block[j]),
else
    fail("can't read MDFAT"),   // okay to read less

fclose(cvf),
printf("\nTotal clusters              %u\n", num_clust),

// print global counters incremented by do_mdfat_entry()
printf("In use:                     %u (%lu%% used)\n",
    clusters_in_use, (100L * clusters_in_use) / num_clust),
printf("Plain sectors (Unc)         %lu\n", sectors_plain),
printf("Compressed sectors (Cmp)    %lu (%lu%% compressed)\n",
    sectors_coded,  100L * sectors_coded) / sectors_plain),
ratio = (10L * sectors_plain) / sectors_coded,
printf("Sector compression ratio:   %u.%u to 1\n",
    ratio / 10, ratio % 10),
if (sectors_coded != 0)
{
    ratio = (160L * clusters_in_use) / sectors_coded,
    printf("DIR /C compression ratio:   %u.%u to 1\n",
        ratio / 10, ratio % 10),
}
// Exercise for the reader (I suddenly got very lazy here)
// To produce DIR /CH use get_dpb(host)->sectors_per_cluster

return 0;
}
```

MDFAT shows compression ratios for a CVF file and also lists any clusters where cCmp is greater than cUnc

```
C:\UNDOC2\CHAP8>mdfat a:\dblspace.000
Expanded clusters (cCmp > cUnc):
Cluster    Sector cCmp cUnc C/U

   33        470   16   12   U
   46        678   16   10   U
  103       2107   16   10   U
  112       2123   16    8   U

Total clusters:             297
In use:                     179 (60% used)
Plain sectors (cUnc):       2288
Compressed sectors (cCmp)   2000 (87% compressed)
Sector compression ratio:   1.1 to 1
DIR /C compression ratio:   1.4 to 1
```

The sector compression ratio is always equal to DIR /C if the original media had 1 sector per cluster. In previous versions of DIR /C the MDFAT program would need to keep count of partial clusters. However, the program would instead use the get dpb() host() >sectors_per_cluster

Windows DoubleSpace. It is important to realize that the actual compression and decompression routines are not part of DoubleSpace. It is done by something called a Microsoft Real Time Compression Interface (MRCI) server that happens to be found inside DBLSPACE.BIN. There can be other MRCI-compatible servers besides DoubleSpace and other MRCI servers. MRCI includes services for compressing and decompressing arbitrary blocks of data in memory. It includes support for multimedia data compression. The interface uses INT 2Fh AX=4A12h and the BIOS service INT 15h AX=E80Fh to find possible hardware-based MRCI servers, and is documented in Microsoft's *MS-DOS 6.0 Encyclopedia—Reference*. Developers can license MRCI libraries for DOS and Windows free of charge from Microsoft, though Microsoft's cover letter to the MRCI license agreement warns that MRCI might be subject to a patent infringement suit from Stac Electronics.

Microsoft, in essence, characterizes the company that licensed (read: gave away) the data compression technology to Microsoft for inclusion in MS-DOS 6/DoubleSpace as sells a nice add-on product—DoubleSpace Enhanced Space Manager. According to the packaging, "We didn't share all our space secrets with Microsoft. We held back our 6 of our crown jewels that'll make your life a lot easier." These include SuperCompress, SelectCompress, CustomScript, and other nifty additions to DoubleSpace.

Stacker Drives

Back to Listing 8-11, ENUMDRV also checks for Stacker drives using the function stacker_driver from IS_STACK.C shown in Listing 8-14.

Listing 8-14: IS_STACK.C

```
/*
IS_STACK.C    Detect Stacker driver, and Stacker drives
Andrew Schulman, July 1993

These calls were documented in the back of the Stacker 2.0 User's
Guide, and are also described in the Interrupt List
*/

#include <stdlib.h>
#include <stdio.h>
#include <dos.h>
#include "currdir.h"

STACKER_DRIVER far *stacker_detect(void)
{
```

```
    static STACKER_DRIVER far *drv = (STACKER_DRIVER far *) 0,
    char far *pbuf,
    char *buf,
    if (drv) return drv;
    if (! (buf = (char *) malloc(1024)))
        fail("Insufficient memory"),
    pbuf = (char far *) buf;

    // Get address of Stacker driver by making an otherwise-illegal
    // INT 25h call
    #define STACKER_MAGIC 0xDCDC0
    _asm push ds
    _asm mov ax, STACKER_MAGIC
    _asm lds bx, pbuf
    _asm mov cx, 1
    _asm xor dx, dx
    _asm int 25h
    _asm popf
    _asm pop ds
    _asm cmp ax, STACKER_MAGIC
    _asm jne no_stacker
stacker
    drv = *((STACKER_DRIVER far * *) &buf[4]),
    free(buf);
    return (drv->signature == 0xA55A) ? drv : (STACKER_DRIVER far *) 0;
no_stacker:
    free(buf);
    return (STACKER_DRIVER far *) 0;
}

int stacker_swapped(int drive)
{
    static STACKER_DRIVER far *driver = (STACKER_DRIVER far *) 0,
    if (! driver) driver = stacker_detect();
    return (driver) ? driver->drive_map[drive] : 0;
}

DWORD stacker_drive(int drive, BOOL *pswap, BYTE *phost)
{
    volatile DWORD drv = 0, // volatile so compiler doesn't just return 0!
    static STACKER_DRIVER far *driver = (STACKER_DRIVER far *) 0;
    int host;
    if (! driver) driver = stacker_detect(),    // one-time init
    if (! driver) return 0L;
    drive++,
    _asm mov ax, 4404h
    _asm mov cx, 4
    _asm mov bl, byte ptr drive
    _asm lea dx, drv
    _asm int 21h
    if (! drv) return 0L;
    drive--;
    host = stacker_swapped(drive);
    *phost = host;
    *pswap = (host != drive);
    return drv,
}

#ifdef TESTING
void fail(const char *s) { puts(s); exit(1); }

main()
{
    int i, lastdrive, swap, host,
    if (! stacker_detect())
        fail("Stacker not installed");
    _dos_setdrive(0xFF, &lastdrive);
```

```
    for (i=0; i<lastdrive; i++)
        if (stacker_drive(i, &swap, &host))
        {
            printf("%c:\tSTACKER", i + 'A');
            if (swap) printf(" (swapped %c:)", host + 'A');
            printf("\n");
        }
    return 0;
}
#endif
```

This code checks for the presence of Stacker using an otherwise invalid INT 25h call, it also accesses Stacker drives by making IOCTL calls to the Stacker driver. These portions of the Stacker API are described in the INTERRUPT database that accompanies this book. Some partial documentation of the Stacker API is available from the Stac Electronics forum on CompuServe.

Earlier we saw that DIR /C in DOS 6.0 produces very odd compression ratios for small files. The same thing has been true for each of Stacker's SDIR utility.

```
C:\STACKER>sdir foo* *
SDIR - 3.00,  (c) Copyright 1990-92 Stac Electronics, Carlsbad, CA

Volume in drive C is STACKER
Directory of  C:\STACKER

FOO      BAR          1 07-20-93  10:09p   8.0:1
FOOBAR   BAR          5 07-20-93  10:19p  16.0:1
        2 file(s)    3137536 bytes free

Overall  compression ratio of files listed = 10.7:1
```

Showing 8:1 compression for a one byte file and 16:1 compression for a five byte file is certainly wrong. Each of these files had four sectors per cluster and thus uses 2,048 bytes each to store these small files. Assuming Stacker uses a single 512 byte sector each to store these small files, the actual compression ratios are 1:1. SDIR's presence is using the maximum 16 sectors per cluster of the Stacker drive, rather than the 4 sectors per cluster of the original host drive. But then why the reported 8:1 compression for the one byte file? Data Stacker is somehow very strange and slightly dishonest about these compression ratios.

The Stacker SDIR utility has an undocumented /D switch that dumps out diagnostics for some of the internal Stacker structures. The Cmap is presumably the cluster map, similar to DoubleSpace's poorly named MIDAS.

```
C:\STACKER>sdir /d sdir.exe
SDIR - 3.00,  (c) Copyright 1990-92 Stac Electronics, Carlsbad, CA

Volume in drive C is STACKER
Directory of  C:\STACKER

SDIR     EXE     35689 06-03-93   3:05a
  First cluster  1986
  Fat: 1989  Cmap: 0084C1D7  Extent: 008802ED
  Fat  198A  Cmap  0086C1FA  Extent  008904ED
  Fat  198B  Cmap  0085C2A1  Extent: 008A02ED
  Fat  198C  Cmap  0083C2D8  Extent: 008C04ED
  Fat  FFFF  Cmap: 0081C364  Extent: 000402ED

Sector Ratio = 1.0 933
Host Cluster Ratio = 0.960:1
Compressed Disk Cluster Ratio = 1.067:1
Adjusted Cluster Ratio = 1.067:1
Percent of original file size: 104.17%

        1 file(s)    3137536 bytes free

Overall compression ratio of files listed = 1.1:1
```

SDIR.EXE itself achieved such low compression here because Star Electronics has already pre-compressed the executable using the excellent LZEXE program by Fabrice Bellard, whose signature "FABV" appears at the end of such compressed executables. Mitugu Kurizono's UNLZEXE can decompress these executables.

Novell NetWare Drives

Because ENUMDRV simply walks the CDS, whose size is set by LASTDRIVE, the program does not show Novell NetWare drives that are assigned to drive numbers that exceed the value of LASTDRIVE. As noted in Chapter 4, the NetWare API includes INT 21h AH=EEh and AH=F2h functions that can be used to display NetWare drives. However, as also explained in Chapter 4, the NetWare workstation shell also provides its own versions of many standard INT 21h calls. A documented MS-DOS 5+ network call, Get Assign List Entry (INT 21h, AX=5F02h), can enumerate NetWare drives. Of course, it also enumerates any non-NetWare network drives that DOS supports.

Even a commercial version of the ENUMDRV program would also have to incorporate code such as that found in Listing 8-15, NETDRV.C, which runs the Get Assign List Entry function in a loop and prints out the local and network names for each network-connected device, including printers as well as drives.

Listing 8-15: NETDRV.C

```
/*
NETDRV.C -- Display network connections, using 21/5f02
Andrew Schulman, July 1993
NOTE: 21/5F02 is *not* undocumented' Is NetWare support for it documented?
*/

#include <stdlib.h>
#include <stdio.h>
#include <dos.h>

typedef unsigned char BYTE;
typedef unsigned short WORD;

int _dos_getassign_ist(WORD index, char far *local, char far *net,
    BYTE *pavail, BYTE *pdevtype, WORD *puserval)
{
    BYTE avail, devtype;
    WORD userval;
    _asm push ds
    _asm push di
    _asm push si
    _asm mov bx, index
    _asm lds si, local
     asm les di, net
    _asm mov ax, 5f02h
    _asm int 21h
    _asm pop si
    _asm pop di
    _asm pop ds
    _asm jc error
    _asm mov byte ptr avail, bh
    _asm mov byte ptr devtype, bl
    _asm mov word ptr userval, cx
    *pavail = avail; *pdevtype = devtype; *puserval = userval;
    return 0;   // success
error:;
    // return value in AX
}

main()
{
    char local[128], net[128];
```

```
    BYTE avail, devtype;
    WORD uservat, i;

    for (i=0; i<0xFFFF; i++)
        if (_dos_getassignlist(i, local, net, &avail, &devtype, &uservat))
            break;
        else
            printf("%u\t%s\t%s\n", i, local, net);
    return 0;
}
```

Running under NetWare 3.11 with LASTDRIVE=Z NETDRV produced the following sample results

```
0       G       \\MRY-APPL-TS\VOL1
1       H       \\MRY-APPL-TS\VOL1
2       I       \\MRY-APPL-TS\SYS
3       J       \\MRY-APPL-TS\VOL2\TOOLS\SRC

12      W       \\MRY-APPL-TS\VOL1
13      Z       \\MRY-APPL-TS\SYS
14      LPT1    \\MRY-MAIL-CORP\GCC1-TS-HPLJ2
15      LPT2    \\MRY-MAIL-CORP\GCC1-TS-QMSPS
16      LPT3    \\MRY-MAIL-CORP\GCC1-HPLJ2-TS
```

You may recall that we were talking about the CDS and then went off to discuss a whole range of drives whose type (RAM disk, DoubleSpace, Stacker, NetWare, or one way or another) is not reflected in the CDS. Let's now return to the CDS itself.

Manufacturing and Removing Drive Letters

All the utilities and functions presented so far in this chapter report back on the state of the DOS file system, but have done nothing. Our next utility changes the CDS. But it's perverse to classify utilities in this manner—data structures they alter. A user would say that this program creates and destroys drive mappings. For example

```
C:\UNDOC2>d r d *

 Volume in drive D is RAMANUJAN
 Directory of  D:\

CHAP1    DOC      4439   6-12-90   9:05a
        1 File(s)   1261568 bytes free

C:\UNDOC2>devoff d:

C:\UNDOC2>d r d
Invalid drive specification
```

Sometimes it's difficult to convince MS-DOS that a logical drive is no longer present. If you have ever worked with the Microsoft CD-ROM Extensions, for example, you might have noted that the only way to reliably unload it is to reboot the machine. Even ISR management programs like the superb MARK/RELEASE from Earth Power Software are insufficient to remove MSCDEX because it is loaded from top-of-memory. MSCDEX also creates a logical drive and that, too, must be undone.

DRVOFF merely calls the curdir function from CURRDIR.C (listing 8.10) and uses the returned CDS pointer to zero the flags word, instantly making the drive invalid. In essence, DRVOFF is nothing more than

```
curdir(toupper(argv[1][0]) - 'A')->flags = 0;
```

This is the attribute that interested one of the authors enough to undoc ument DOS to work on this book. However, DRVOFF does not actually work as well as its intended purpose of unloading MSCDEX from memory, as the notes at the top of DRVSET.C in Listing 8-16 indicate.

Access to the CDS is used for invalidating drive letters. With a TSR called DRVSET, you can activate an invalid drive letter in a variety of ways simply by turning on some bits in the flags word. DOS immediately recognizes the new drive as valid, so that you can change to it and send it requests (all of which fail, of course):

```
C:\UNDOC>e
Invalid drive specification

C:\UNDOC>dir e
Invalid drive specification

C:\UNDOC>drvset e  net phys
NET PHYSICAL

C:\UNDOC>dir e

 Volume in drive E has no label
 Directory of  E:\

File not found

C:\UNDOC>e

E:\>chkdsk
Cannot CHKDSK a Network drive
```

Simply by invalidating bits in the CDS we convince DOS that E: is (or was) a valid drive. Since DIR does not show us the specific error code, what value does this have? However, this is the foundation for creating drives with the network redirector. Simply by making drive E a network drive again, the same network redirector means a new FAT-less installable file system can service all DOS file requests for that drive—or an INT 21h interface. The handler I later on in this chapter we will such a handler for the CD-ROM. DRVSET is useful for experimenting with drives, which are the foundation for installable file systems under DOS.

Since DRVOFF and DRVSET have so much in common, it makes sense to package them in the same source module, DRVSET.C (Listing 8-16). The resulting program behaves differently, however, depending on its program name. argv[0] in C contains the string, "DRVOFF."

Because DRVOFF (DRVSET) calls the undocumented function to get a far pointer to the CDS, we can't use the specific drive information with the GET_DRIVE module (see Listing 8-10).

Listing 8-16: DRVSET.C

```
/*
DRVSET.C    Set attributes of drive (CDS entry) given on command line
Andrew Schulman, revised July 1993

NOTE  This (in its DRVOFF form) was the stupid program that got me
interested in undocumented API calls, back in 1989 when I was working
on CD/Network for David Maxey at Lotus. It was part of something
that our customers (especially Shearson) wanted to unload MSCDEX,
called NOMSCDEX.  When Shearson talks, Lotus listens.) Basically,
NOMSCDEX was a batch file that ran MARK/RELEASE and then DRVOFF.

Based on a casual disassembly of MSCDEX (which I did on the urging of
Brian Livingston, who correctly suggested there was something fishy
going on here), it is now clear to me that DRVOFF doesn't truly work
for unloading MSCDEX, because MSCDEX *patches* DOS.  A true NOMSCDEX
would back out these patches too.  Or do the patches occur
only when running MSCDEX /S on a server, so that using DRVOFF for
NOMSCDEX *would* work except when running MSCDEX /S?  Anyhow,
programs like MSCDEX do enough gross low-level things to DOS that
trying to back out the changes and unload them is a risky
proposition at best.
```

```
*/
#include <stdlib.h>
#include <stdio.h>
#include <string.h>
#include <ctype.h>
#include "currdir.h"

void fail(char *s) { puts(s); exit(1); }

main(int argc, char *argv[])
{
    char *cmd;
    CDS far *drv,
    int drive, drvoff, i,

    /* to just turn off drives, rename program DRVOFF */
    drvoff   (strstr(strupr(argv[0]), "DRVOFF") != 0),

    /* what drive do they want? (accepts letters and numbers) */
    if (argc < 2) fail(drvoff?
         usage  drvoff [drive]"
         usage  drvset [drive] NET PHYS REDIR SUBST JOIN OFF COPY [drv2] "
                               "BACKOFF [ofs]");

    drive = toupper(argv[1][0]) - 'A';
    if (! (drv = currdir(drive)))
        fail("can't get current directory structure"),

    if (drvoff) { drv->flags = 0; return 0; }   /* just turn off drive */

    for (i=2; i<argc, i++)
    {
        cmd = strupr(argv[i]);
        if (strstr(cmd, "COPY"))    /* COPY one CDS entry to another */
        {
            CDS far *drv2   currdir(toupper(argv[i+1][0]) - 'A'),
            if (! drv2) fail("can't copy from invalid drive"),
            _fmemcpy(drv, drv2, (_osmajor >= 4) ? 0x58   0x51),
            i++,
            continue,
        }
        else if (strstr(cmd, "BACKOFF")) /* set backwack offset */
        {
            drv->backslash_offset = atoi(argv[i+1]); i++;
            continue,
        }
        /* COPY and BACKOFF let you simulate SUBST  (Big deal!) */

        /* change drive attributes */
        if (strstr(cmd, "OFF"))     drv->flags = 0;
        if  strstr(cmd,  CDROM ))   drv->flags |= REDIR_NOT_NET,
        if (strstr(cmd,  REDIR ))   drv->flags |  REDIR_NOT_NET,
        if (strstr(cmd, "NET"))     drv->flags |= NETWORK,
        if (strstr(cmd, "SUBST"))   drv->flags |= SUBST,
        if (strstr(cmd, "JOIN"))    drv->flags |= JOIN,
        if (strstr(cmd, "PHYS"))    drv->flags |= PHYSICAL;
    }

    /* print current drive state */
    if (! drv->flags)           fputs("INVALID ", stdout);
    if (drv->flags & REDIR_NOT_NET) fputs("REDIR ", stdout), // CDROM
    if (drv->flags & NETWORK)   fputs("NET ", stdout),
    if (drv->flags & SUBST)     fputs("SUBST ", stdout),
    if (drv->flags & JOIN)      fputs("JOIN ", stdout);
    if (drv->flags & PHYSICAL)  fputs("PHYSICAL ", stdout);
    putchar('\n'),
    return 0,
}
```

DRVSET also has an option to copy from one CDS entry to another and an option to set the CDS backslash offset (not an unnecessary and somewhat bogus but perhaps enlightening way this simulates the effect of the SUBST command

```
D:\UNDOC2>dir e
Invalid drive specification

D:\UNDOC2>drvset e. copy d  subst backoff 9
SUBST PHYSICAL

D:\UNDOC2>dir e

 Volume in drive E has no label
 Volume Serial Number is 1B51-11E7
 Directory of E:\

.            <DIR>      02-16-93  11 52a
..           <DIR>      02-16-93  11 52a
NAMCLUST EXE       9812 07-14-93   7 31p
CLUSTNAM EXE       8102 07-10-93  10 42p
CHAPB    TXT     321850 07-20-93   8 49a
; ... etc ...
```

This is close enough to the actual effect of SUBST that an examination of the code in DRVSET should give a reasonable idea of how the real SUBST command must work

```
CDS far *dest = currdir('E' - 'A'),
CDS far *src = currdir('D' - 'A'),
_fmemcpy(dest, src, _osmajor >= 4) ? 0x58 : 0x51),
dest->flags    SUBST,
dest->backslash_offset   _fstrlen(src->curdir),
```

As another example of modifying the CDS see the NETDRV program in Chapter 2 which changes the network redirector's drive letter (that is the LANTDRIVE value in the CDS

For now we're interested only in getting drives and directories. So get yourself another cup of coffee and another slice of pizza and proceed to the next installment in our saga of the DOS file system. It's now time to look at the data structures that DOS uses when you open a file.

System File Tables (SFTs) and Job File Table (JFT)

The System File Tables are the backbone of the DOS file system and have been present in DOS since version 2.0 when Microsoft added tree-based file operations. Before that DOS used File Control Blocks (FCBs which are discussed briefly later in this chapter. An SFT maintains the state of an *open* file. It includes such things as the device (or with a directory entry and what cluster to start keeping track of the current position within the file (the file pointer, determining current file size and maintaining date and time stamps when a file is modified. All information contained in the directory entry for the file comes from the SFT when the file is closed it is brought back into the SFT when the file is opened

When a program opens a file using DOS function 3Dh Open File or 6Ch Extended Open/Create) or creates a file and that file refers to the file when reading with function 3Fh writing with function 40h and so on. The file handle is what Microsoft calls a "magic cookie" meaning that you can use it but don't access the object in this case a file without assigning any particular meaning to the handle For example

```
#include <io.h>
// ...
char buf[12];
int f = open("foo.bar", O_RDONLY),
if (f == -1) fail("couldn't open file!"),
read(f, buf, 12),
close(f),
```

Assuming that [illegible] that is that the file was successfully opened most applications treat file handles as [illegible] Accordingly such as open returns the handle to you and you faithfully pass [illegible] such as read write and close With the exception of the predefined handles (0 stdin 1 stdout 2 stderr and sometimes 3 stdaux and 4 stdprn) applications generally attach no [illegible] to the numeric value of a file handle DOS however certainly does attach meaning to the [illegible] and it's sometimes useful for an application to do so too

When DOS creates a file handle it does not return INT 21h functions 3Dh and 6Ch simply an [illegible] of a series of structures the Job File Table [illegible] is an array of BYTEs indexed by file handles and holding SFT indices In other words

```
int f = open(...);
sft_index = jft[f];
sft_entry = sft[sft_index];

or

sft_entry = sft[jft[f]];
```

When [illegible] Novell NetWare versions 2 and 3 which as discussed in Chapter 4 assign [illegible] files to [illegible] on network servers NetWare uses this as a reverse index into its own [illegible] to [illegible] the [illegible] pointing to the SFT

Although DOS [illegible] single system SFT its JFT is Many pointers to the first SFT in the chain can be found at [illegible] Each DOS process has its own JFT a far pointer to a process's JFT can be found at offset 34h in its PSP (see Chapter 7

FILE* vs. File Handles

Before we go any further, we need to to distinguish DOS file handles from the file identifiers used in compiler run time libraries Many DOS applications use a compiler run-time library rather than calling directly down to DOS In some cases, like the C open() function declared in IO.H the DOS version of the C run-time library usually does happen to return a DOS file handle However in other cases, such as the C fopen() function declared in STDIO.H, something completely different is returned fopen() returns a pointer to a FILE structure (FILE *)

FILE is a structure declared in STDIO.H It is an indication of the success of the C run-time library that most programmers think purely of FILE* without having to give any consideration to and perhaps without ever having looked at FILE itself The C run-time library decodes a handle, or FILE* which given a FILE* can return the corresponding file handle that the application would have had it called open() rather than fopen(). In most C compilers for the PC the FILE structure contains a field for the DOS file handle, and fileno() simply returns the value of this field:

```
#include <stdio.h>
//
FILE *f = fopen(...);
sft_entry = sft[jft[fileno(f)]];
```

The superficial similarity between FILE* and file handles is a surprisingly large source of confusion The technical support department for one vendor of programmer's products reports the confusion between FILE* and a DOS file handle as one of the most frequently occurring problems among its (supposedly quite sophisticated) clientele This confusion is particularly rampant among those trying to increase the number of available file handles. They call INT 21h AH=67h to get more DOS file handles and then wonder why fopen() still fails after twenty open files. We'll get to this topic later in this horrendously long chapter

All DOS systems have at least two SFT entries; many have 20 or more. Just as the LASTDRIVE value in CONFIG.SYS sets the size of the CDS, FILES establishes the number of SFT entries. Incidentally, here's an excellent answer to an end user's question: "What exactly does the FILES directive in CONFIG.SYS do?" See Jeff Prosise, "What FILES Does," *PC Magazine*, November 12, 1991. FILES=40 tells DOS to set up 40 such entries. Most CONFIG.SYS files handle that a program asks to open a file, DOS finds through the JFT one of the SFTs.

When you ask DOS to open a file, by calling function 3Dh or 6Ch, or by calling a higher-level function like fopen(), the run-time library eventually calls one of the DOS functions for you. The following takes place:

First, DOS uses the current PSP (see Chapter 6) to locate your JFT. (Actually, the JFT is at whatever PSP happens to be the current PSP. Let's assume for this discussion that the current PSP belongs to your program. Through terminate-and-stay-resident programs (TSRs), DOS searches through the current PSP's JFT to find a slot that is not in use. DOS then records the index into the table for the first such free slot that it finds. DOS ultimately converts this JFT entry's index into the file handle associated with the open file, assuming all goes well. If DOS scans its JFT slot but cannot find a free one, DOS can't open the file and doesn't need to do anything more. DOS would return to your program with error code 4 (too many open files). A program can increase the size of its JFT using function 67h (Set Maximum Handle Count), discussed later in this chapter.

In the rare event of finding a free JFT entry, DOS next searches the chain of SFTs looking for the first SFT entry that is available for use. If no such entry is found, again DOS fails the file open and returns error code 4 (for this SFT full situation, which is normally cured at the shell prompt from JFT full—calling function 67h to increase the JFT size does not help; the best bet is to raise FILES in CONFIG.SYS and reboot. Though you will see later that there's another way to get more SFT entries.

If both a free handle (JFT entry) and a free SFT entry exist, DOS calls the SHARE file-sharing hook function. (See the discussion of SHARE later in this chapter.) Assuming SHARE allows the file open to succeed, DOS determines the drive for the file you asked to open and uses that to index into the CDS, locating the proper CDS entry for the drive where you requested the file resides. If you passed no drive portion to such as "FOO.BAR", DOS uses the current directory in the CDS. (Internally, the couple of hidden ASSIGN, APPEND, and LASTOPEN do their work.)

Every time DOS does not locate a file, it checks to see if you're opening one on a network drive. If so, DOS issues the appropriate INT 2Fh AH=11h hook to have any installed network redirectors open the file. As noted at the start of this discussion of the network redirector interface, when DOS calls one of the Open-and-create redirector functions (INT 2Fh AX=1116h, AX=1117h, or AX=1122h), it passes the redirector a freshly initialized SFT entry, which it expects the redirector to fill in.

If you're creating what's a new entry, DOS also uses the CDS's current-directory pointer to the Drive Parameter Block (DPB). DOS uses the DPB to locate the device driver. A request from the redirector to convert a drive letter to a DOS device driver that handles the drive. From the device driver header, DOS locates function pointers to the driver's Interrupt and Strategy routines, which it calls to issue actual I/O to and from the drive.

Armed with the drive information from the DPB, the DOS kernel calls the device driver to read the drive's root directory into one of the DOS buffers (unless, of course, the root directory is already located in one of the buffers, recall from the BUFFERS program listing 8.8 that the buffers often include directory and FAT sectors).

If the supplied path contains subdirectories, the DOS kernel searches the root directory of the drive, trying to match the first component of the supplied path (e.g., the "UNDOC2" in "C:\UNDOC2\CHAP8\FOO.BAR"). If it can't find the function fails with "Path not found" (error code 3).

If DOS finds this top-level directory, however, it then converts the starting cluster value in its directory entry to an LSN. It then passes the LSN to the device driver, which reads that subdirectory into another buffer or uses it to locate the subdirectory if it's already in the buffers. This process continues until DOS has traversed all directories in the supplied path string, and only the filename remains to be located.

All this is quite similar to the code shown earlier in NAMETEST (Listing 8-5), which turns a file or directory name into a starting cluster number. For example:

```
C:\UNDOC2\CHAP8>nametest foo bar
```

NAMETEST first calls truename to convert "foo\bar" into "C:\UNDOC2\CHAP8\FOO.BAR", and then calls getdpb so drive C: gets the information necessary to read in its root directory. After reading in the root directory, it searches for "\UNDOC2", just as MS-DOS itself would if we issued an INT 21h AH=3Dh to open that file:

```
C:\>nametest undoc2
C:\UNDOC2 ==> 48 (sect 973, 0x000003cd)
```

Armed with \UNDOC2's starting cluster number as found in its entry in the root directory, DOS would read in this subdirectory's cluster of course. DOS first checks the buffers; DOS would next search for a \UNDOC2\CHAP8 subdirectory for \CHAP8. If CHAP8 is not found in the first cluster of this subdirectory, DOS looks for a possible next cluster for the subdirectory and searches there, too. Again, this is similar to the operation of NAMETEST:

```
C:\UNDOC2>nametest chap8
C:\UNDOC2\CHAP8 ==> 51 (sect 1021, 0x000003fd)
```

Assuming CHAP8 is found, DOS again gets its starting cluster number and reads in that cluster. It is now at the final level in the file name, "FOO.BAR".

At this point and not earlier, DOS determines whether you are dealing with a real file or with a named character device, such as CON or LPT1. It does so by searching the list of installed device drivers (see the device driver chain walker program in Chapter 9). If DOS finds an exact match for the file's name portion of the pathspec you gave it—it ignores any extension in this test—it opens the device rather than a file. This means that all the named devices seem to exist in all directories of the file system—but also that a seemingly valid directory named DEV (even though DIR DEV fails) also means that you cannot open or build a file regardless of extension with the same name as one of the installed devices. This is why, for example, "README" would be a very bad name for a device installing this device would prevent you from accessing a README file. This is one reason device names usually are common words and tend to include dollar signs, for example, "CLOCK$".

If no matching device name is found, DOS searches the list directory for the filename and the extension. Again, this can be simulated with NAMETEST:

```
C:\UNDOC2\CHAP8>nametest foo.bar
C:\UNDOC2\CHAP8\FOO.BAR ==> 5578 (sect 89421, 0x00015e4d)
```

Assuming the file or device is found, DOS sets the reference count in the first free SFT allocated earlier to 1 and the index of this SFT entry is stored somewhere in the program's PFT. DOS will later return the "somewhere" part to the calling program as the file handle. If DOS can't match the name, it instead returns error code 2 ("file not found").

What happens next depends on whether you're opening a file or a device. For a file, DOS copies all pertinent information from the file's directory entry into the corresponding fields of the SFT entry. One of these fields has the starting cluster for the file. DOS also copies in a pointer to the DPB for the drive on which the file resides; the DPB in turn points to the device driver header for this device. DOS also sets the file pointer field in the SFT to zero, indicating the beginning of the file. For a device, the SFT entry includes a pointer to the device driver header.

For both files and devices DOS then returns to you with the AX register set to the handle value that it reserved at the start of the process. You now refer to the file using that handle, the magic cookie. As you soon see, this file handle is merely an index into the current PSP's JFT, and the byte at that index in the JFT is in turn an index into the SFT.

If you're creating a new file rather than opening an existing one, this same basic sequence of events is followed, with one significant difference occurring when the SFT entry has been filled out before the DOS kernel comes back to you with a handle. The new directory entry for the just-created file is put back into the DOS buffer for that LSN, and the dirty bit for that buffer is set. By FLUSHERS.C (Listing 8-8), you set this to tell DOS to write the buffer out to disk as soon as possible, certainly before reassigning it. At last, a directory entry is created immediately for your new file, though with a length of zero.

Each time you read from or write to the file, referencing it by means of the handle, DOS uses the supplied handle to index into the JFT associated with the current PSP and it uses the value it finds there to index into the SFTs. The handle is then used to perform the requested operation on the file or device represented by its corresponding SFT entry. The file pointer and date/time stamps in the SFT are updated accordingly. Data transfers also normally involve the DOS buffer cache. To summarize:

```
current PSP -> JFT -> SFT -> buffers, DPB, device driver
```

When you close a file, DOS accesses its SFT just as for reading or writing. If the file has been written to, as indicated by various bits in the SFT attribute word, DOS updates its directory entry with information stored in the SFT, which reflects the latest size, time, and date. Also any dirty buffers is flushed to disk. If the file hasn't been written to, DOS skips these steps.

DOS decrements the handle count field of the SFT entry (for quickest access, the first field) to reflect the fact that one less handle is using this opened-file SFT. The SFT index in the JFT handle table is replaced by the value FFH, which indicates an unused available slot. Because FFH = 255, it indicates free JFT entries even if only a default SFT [with FILES = 20] is present. So, the useful value you can't set. However, remember that Novell NetWare uses negative file handles, as discussed in Chapter 4, setting a very large FILES= value can *reduce* the number of files you can open on NetWare servers.

If the newly freed SFT entry was the only one using the SFT, DOS decrements the handle count, brings it back to 0, and makes the entry available for reuse the next time someone calls DOS 0Fgcv or 0Cxxh. Some programs keep multiple files open with handles, but despite many programs' insistence on having 50 or 100 files available, this is rare for the vast majority of SFTs in use. Programs may grow much larger, but 15 or 20 files are usually more than enough. We'll work with the FILES program a little later on, when you look at the SFT there usually isn't much to see.

How Many FILES?

Earlier, we walked through the DOS disk buffers to determine the value of BUFFERS=; we can likewise walk through the SFTs to determine the value of FILES=. Just as with BUFFERS=, this value is normally set in CONFIG.SYS, though you can alter it on the fly with a utility like Quarterdeck's FILES.COM.

SFTWALK.C (Listing 8-17) determines the value of FILES= and prints out the address and size of each SFT. We've taken some near-code in Chapter 3 (see Listing 3-5), which showed how to port this real-mode code to protected mode Windows. The result was a second version of CONFIG.SYS (Listing 8-18), which used DOS calls and/or Windows API calls. Here, we focus on SFT issues.

SFTWALK determines the FILES= value by threading through the SFT chain and keeping count of the entries in each table. The first SFT always holds five possible open file entries, as assembled in the MSDOS.SYS. If FILES=40 appears in CONFIG.SYS, for example, then DOS allocates a second SFT large enough for 35 more files and chains it to the first SFT. Since each

header consists of a count of the number in its associated table, together with a pointer to the next header, it's easy to count the possible files.

If DOS FCBS is enabled, SFTWALK can also determine the value of FCBS= by walking the chain of System FCBs. These have the same format as the SFTs. We briefly discuss System FCBs later in this chapter.

Listing 8-17: SFTWALK.C

```
/*
SFTWALK.C -- Count FILES= by Walking SFTs
for protected mode Windows version, see \UNDOC2\CHAP3\SFTWALK.C
Andrew Schulman, March 1993
from  Undocumented DOS , 2nd edition (Addison-Wesley, 1993)
*/

#include <stdlib.h>
#include <stdio.h>
#include <string.h>
#include <dos.h>

typedef unsigned char BYTE;
typedef unsigned short WORD;

typedef struct _sft {
    struct _sft far *next;
    WORD num;
    // the actual SFT entires start here
    } SFT;

int sftwalk(int offset, char *name)
{
    static BYTE far *sysvars = (BYTE far *) 0;
    SFT far *sft;
    int files = 0;
    if (! sysvars)
    {
        _asm mov ah, 52h
        _asm int 21h
        _asm mov word ptr sysvars+2, es
        _asm mov word ptr sysvars, bx
        if (! sysvars) return 0;
    }
    sft = *((SFT far * far *) &sysvars[offset]);

    while (FP_OFF(sft) != 0xFFFF)
    {
        files += sft->num;
        printf("%s = %Fp    %u files\n", name, sft, sft->num);
        sft = sft->next;
    }
    return files;
}

main()
{
    int files, fcbs;
    files = sftwalk(4, "SFT");
    printf("FILES=%d\n\n", files);
#ifdef DO_FCBS
    fcbs = sftwalk(0x1A, "System FCB table");
    printf("FCBS=%d\n", fcbs);
#endif
    return files;
}
```

Even if Windows or a program such as QEMM's FILES.COM has added an SFT (and possibly loaded it into upper memory), SFTWALK finds it. For example:

```
C:\UNDOC2\CHAP8>sftwalk
SFT @ 0116:00CC -- 5 files
SFT @ 1014:0000  + 35 files
FILES=40

C:\UNDOC2\CHAP8>\qemm\files +10
FILES=40 before
10 files added
FILES=50 now

C:\UNDOC2\CHAP8>sftwalk
SFT @ 0116:00CC -- 5 files
SFT @ 1014:0000 -- 35 files
SFT @ 1838:0000 -- 10 files
FILES=50
```

From the SFTWALK output, you can see that the earlier mention of sft[ft] was an oversimplification. Because there's a chain of several SFTs rather than a single array indexing into the SFT requires walking the linked list to first find the correct table. For example, in the above configuration, sft[18] would be somewhere in the second SFT table that starts at 1014:0100.

But what's in this data? Let's look at the size of each SFT entry. We've talked a lot about how DOS uses SFTs and about how to walk the SFT list, but we haven't yet seen what an SFT entry looks like. Usually the SFTs are mostly empty, so there's not much to look at, but we can create a busier SFT by running Windows, which keeps many files open. After running SFTWALK within a Windows DOS box to get the address of each SFT in the SFT chain, we can then use DEBUG to look at one of the SFTs:

```
C:\UNDOC2\CHAP8>debug sftwalk.exe
-g
SFT @ 0116:00CC    5 files
SFT @ 1014:0000 -- 35 files
SFT @ 1838:0000 -- 10 files
FILES=50

Program terminated normally
-d 1014:0000
1014:0000  00 00 19 18 23 00 01 00-00 00 20 42 10 A4 13 16      ....#..... B....
1014:0010  01 F9 08 40 19 6A 18 C0-16 00 00 00 02 00 00 00      ...@.j..........
1014:0020  00 F1 01 00 00 03 45 47-41 38 30 57 4F 41 46 4F      ......EGA8OWOAFO
1014:0030  4E 00 00 00 00 01 00 0D-1F 00 00 F9 08 00 00 00      N...............
1014:0040  00 01 00 00 00 20 42 10-A4 13 16 01 F7 08 40 19      ..... B.....@.
1014:0050  6A 18 B0 20 00 00 A0 1E-00 00 00 00 F1 01 00 00      j.. ............
1014:0060  02 45 47 41 34 30 57 4F-41 46 4F 4E 00 00 00 00      .EGA4OWOAFON....
1014:0070  01 00 0D 1F 00 00 F7 08-00 00 00 00 01 00 00 00      ................
```

What have we got here? Each SFT starts off with a header shown in SFTWALK as a DWORD pointer to the next SFT (-1 if this is the last SFT), followed by a WORD which indicates the number of files allowed by this SFT, followed by SFT entries themselves. In the SFT at 1014:0000, the first four bytes (00 00 19 18h) indicate that the next SFT is at 1819:0000; the next two bytes (23 00h) indicate that there are 23h (35) files, just as SFTWALK reported.

SFTWALK doesn't look at the SFT entries themselves, but from the DEBUG hex dump you can plainly see the filenames EGA80WOAFON and EGA40WOAFON. Notice that the SFT includes only the 8.3 name and extension, not the full pathname. However, the SFT also includes the starting cluster for each file, as we know from the CLUSNAM program. If necessary, you can trace this starting cluster into the full pathname.

One could determine the size of an SFT entry simply by subtracting the start of one filename in the hex listing from the start of the next; for example, offset "EGA40WOAFON" (0070h) minus offset "EGA80WOAFON" (0044h) equals 26h = 38h bytes. As crazy as it sounds, there's code in Windows

DOS does not this see "CON CON CON CON CON" in Chapter 1. Programs that want to deal with SFTs over the widest range of DOS versions have to somehow deal with the fact that the SFT size and exact offsets vary in DOS 2.0, DOS 3.0, and DOS 3.1, and of course may change again in future DOS versions (though so far it has remained stable from DOS 3.1 through DOS 6.0).

In DOS 3.0 and higher, each SFT entry is 3Bh bytes, and the filename is located at offset 20h in each entry. We use this information in our next program, which also takes us back to look more closely at the JFT and its relation to the PSP.

Filename From Handle

So far, we've seen how to find the name of a file and have only its handle available. One important example of this is when you use the DOS redirection facility to redirect stdout to a file rather than to CON: its normal destination. While the stdout handle is always 1, there's no documented way of telling from inside a running program the *name* of the file to which this or any other handle corresponds.

This next program, H2NAME.C (Listing 8-18), converts file handles to names by combining several undocumented DOS features. It consists primarily of the function o2name(), which, when passed a PSP and a handle, returns the filename to which that PSP:handle combination corresponds.

While the main purpose of the function o2name() and of other programs, H2NAME.C also includes a test driver. If you run H2NAME with a PSP number on the command line, you can get the PSP:handle combinations for processes from the UNDELM program in Chapter 7. H2NAME enumerates all open files belonging to that process. Otherwise, it enumerates all open files belonging to H2NAME itself. Among the psp global from Lattice C compiles for the PC. To see anything interesting, you'll want to run it so that it redirects output, so you should redirect H2NAME's output to a file so that this redirected output file shows up in the enumeration. H2NAME sends its output to stderr, so the output is still visible. You can also use it to check on a program's unusual input.

```
C:\UNDOC2\CHAP8>h2name > foo bar < h2name.c
Files for 7976
 0 ==>  3   > H2NAME  C
 1   >  4   > FOO     BAR
 2  ==> 1 ==> CON
 3 =>  0   > AUX
 4  ==> 2   > PRN
```

Standard input (stdin) is always file handle 0. Here we can see that stdin has been redirected from H2NAME.C (note that SFT entry 3 contains input). Standard output (stdout) is always file handle 1, and again, sure enough, H2NAME knows its standard output has been redirected to the file FOO.BAR with SFT entry 4. We made no effort to redirect stderr, so this file handle 2 shows up in the H2NAME output as CON.

Only the name and extension are reported. Getting a complete pathname would require using the CLUSTNAM code (Listing 8-6) to process the starting cluster number stored in the SFT.

Listing 8-18: H2NAME.C

```
/*
H2NAME.C -- Convert file handle into file name.
Jim Kyle, 1991, Revised Andrew Schulman, July 1993

The file handle is a JFT index.  JFT[handle] is an SFT index.  The
SFT contains information on the file, including the name.  However,
H2NAME only gets the name and extension.  To get the full pathname,
convert cluster number in SFT entry to a pathname (see code in
CLUSTNAM.C to see how to turn clusters numbers into full pathnames).
*/

#include <stdlib.h>
```

```
#include <stdio.h>
#include <string.h>
#include <dos.h>
#ifdef __TURBOC__
#include <mem.h>
#else
#include <memory.h>
#endif

#ifndef MK_FP
#define MK_FP(s,o) ((void far *)\
    (((unsigned long)(s) << 16) | (unsigned)(o)))
#endif

char * h2name( unsigned psp, int h, int *sft_handle )
{ static char name[15],  /* will hold file's name */
  static unsigned far *sft_ptr = (unsigned far *) 0;
  static unsigned nmofs,
  static int sftsize,
  unsigned far *ptr,
  signed char far *sptr, far *htbl;
  int sftn,

  memset( name, 0, 15 ), /* blank out the static name */

  /* create pointer to handle table (JFT) */
  htbl = *((char far * far *) MK_FP(psp, 0x34));

  if (! sft_ptr)    /* one-time initialization to get SFT info */
  {
      _asm mov ah, 52h
      _asm int 21h
      _asm les bx, dword ptr es:[bx+4]  /* SFT chain = SysVars[4] */
      _asm mov word ptr sft_ptr+2, es
      _asm mov word ptr sft_ptr, bx

      switch( _osmajor )
      {
        case 2  sftsize = 0x28, nmofs = 4; break;
        case 3  sftsize = 0x35, nmofs   (_osminor == 0) ? 0x21   0x20, break,
        default: sftsize = 0x3B, nmofs = 0x20; break;   // DOS 4.0, 5.0, 6.0
      }
  }

  ptr = sft_ptr;
  *sft_handle = htbl[h],
  if (htbl[h] >= 0)             /* now if handle is valid    */
    { sftn = htbl[h];           /* get index into SFT list */
      while ( FP_OFF(ptr) != 0xFFFF )
        { if (ptr[2] > sftn)  /* then target is here */
            { sptr = (unsigned char far *)&ptr[3];
              while (sftn--)  /* so skip down to it */
                sptr += sftsize;
              _fmemcpy( name, &sptr[nmofs], 11 );
              return name;    /* found and copied; done */
            }
          sftn -= ptr[2];     /* not here; reduce index  */
          ptr = (unsigned int far *) MK_FP( ptr[1], ptr[0] ),
        }
    }
  strcpy( name, "UNKNOWN" ),
  return name;                  /* reached only by error      */
}

void fail(const char *s) { puts(s); exit(1); }

main( int argc, char *argv[] )
{
    char *s,
```

```
    unsigned psp;
    signed int max_files, sft_handle, jft_handle,

    if (argc < 2)
        psp   _psp,                 /* display files for this program */
    else
        sscanf(argv[1],  %X , &psp), /* take PSP from command line */

    max_files = ( osmajor >  3) ? *((int far *) MK_FP(psp, 0x32)) : 20;

    if (*((unsigned far *) MK_FP(psp, 0)) != 0x20CD) /* check for INT 20h */
        fail("that's not a PSP!"),

    fprintf(stderr, "Files for %04X\n", psp);

    for  jft_handle 0, jft_handle<max_files, jft_handle++)
    {
        s = h2name(psp, jft_handle, &sft_handle),
        if (sft_handle < 0)
            fprintf(stderr,  %2d ==> %2d\n ,
                jft_handle, sft_handle),    // unused, or Novell
        else
            fprintf(stderr,  %2d  => %2d ==> %s\n ,
                jft_handle, sft_handle, s),
    }

    return 0;
}
```

The routine h2name() works like this. The PSP contains a pointer to the JFT and usually the JFT is only 20 bytes long. The function first creates a far pointer to the handle table for the specified PSP. It then calls INT 2Fh AH=52h, Get SysVars, to set up the SFT pointer and two variables, sftsize and sftoffset. The sftsize field is the size of each entry in the SFT, and sftoffset is the offset within the SFT of the file or device name, based on the DOS version in use.

With these preliminaries out of the way, h2name() uses the supplied handle value as an index into the JFT. If the value found there is not negative, indicating a valid handle, it is an SFT index. Recall that negative file handles have special meaning in Novell NetWare.

The routine then walks through the linked list of SFTs until it finds the SFT containing the desired index, sft_ptr[2]. As in printf's %n format, this program's admittedly odd way of saving strings: files. Each time it "skips over" an SFT, the number of entries in the skipped block is subtracted from the desired index. Therefore, sft_ptr[2] is the index relative to the current block rather than to the absolute beginning of the SFT linked list.

When the correct block is found, a pointer is set to the first byte of its first SFT entry (sftptr = &sftptr[4]), and the SFT entries are skipped (sftptr += sftsize), decrementing the index each time, until it is down to zero. When this happens, the SFT entry under the pointer is the one you're looking for. The name field offset is then added to sftptr, the chosen bytes at the resulting location are copied into the static buffer name, and the program returns a pointer to the first byte of the buffer.

Readers could apply this same technique to other information found in the SFT, h2attrib, for example, would return the file attributes rather than the filename, and h2cluster()—well, you get the idea.

H2NAME.C calls h2name() for each JFT entry. H2NAME's ability to look at the JFT for any PSP specified on its command line will come in handy later when we need to test the FHANDLE and FILES programs. If H2NAME were built as a Windows program, using the techniques shown in FILES.C (Listing 8-19) and explained further in Chapter 8, it could reveal the JFT for KRNL386 or any other program running in the System VM. As Chapter 3 noted, Windows programs have PSPs, just as DOS programs do.

What Files Are Now Open?

Our next utility, FILES, displays information about all open files and devices on your system. Normally there aren't many open files in the SFTs to see anything other than AUX, CON, and PRN redirect FILES's output to a file, for example, `files > files.log`, or unnecessarily redirect input from a file, `files < foo.bar`:

```
D:\UNDOC2>files > files.log < foo.bar

D:\UNDOC2>type files.log
#   Filename          Size   Attr  cRef  Owner   Cluster, DD, DPB
-   --------          ----   ----  ----  -----   ----------------

[SFT @ 0116:00CC -- 5 files]
0   AUX      .           0   0000     7  9077    DEV 0070 0035  0
1   CON      .           0   0000    19  9077    DEV 0070 0023  0
2   PRN      .           0   0000     7  9077    DEV 0070:0047  0
3   FOO       BAR     7391   0020     2  6AC2    D  29444  DPB 0FF1 0000  0
4   FILES    .LOG        0   0020     2  6AC2    D      0  DPB 0FF1.0000  0

[SFT @ 1014 0000 -- 35 files]

[SFT @ 1858:0000 -- 10 files]
```

Why was input or output redirected, FILES inherits an open file from COMMAND.COM. Note how FOO.BAR and FILES.LOG each have a reference count of 2.

You can run CLUSNAM to confirm the cluster numbers FILES displays. Only one file in the SFT, FOO.BAR, has a cluster number. FILES.LOG, to which output from the FILES program was redirected, was at the time, of course, just a directory entry with no associated data clusters.

```
D:\UNDOC2>clusnam d: 29444
D:\UNDOC2\FOO.BAR
```

Besides showing that the output from FILES is accurate, this also shows that the CLUSNAM code (Listing 8.5) could be moved into FILES to output the full pathname for each SFT entry with an associated data cluster. The same point was made earlier regarding the TREENAME program's shortcomings. The CLUSNAM code may take a long time to run.

As you'll see in FILES.INC (Listing 8.19), the owner FILES displays comes right out of the SFT. Often this is a PSP, but you'll recall that FILES will use the CDMIM code from Chapter 7 to turn the owner's PSP address into a readable name.

However, these values aren't always legitimate PSP addresses. The AUX, CON, and PRN entries show a value of 9077h. Running CDMIM indicates that this is not a valid PSP. Instead the value is apparently the address of a PSP at the time that the SYSINIT initialization code in IO.SYS or IBMBIO.COM opened them. SYSINIT relocates itself to the top of memory, accounting for the high address.

As a more interesting example, consider the output from FILES when running in a DOS box under Windows 3.1 Enhanced mode:

```
D:\UNDOC2>files
#   Filename          Size   Attr  cRef  Owner   Cluster, DD, DPB
-   --------          ----   ----  ----  -----   ----------------

[SFT @ 0116:00CC -- 5 files]
0   AUX      .           0   0000    17  9077    DEV 0070:0035  0
1   CON                  0   0000    51  9077    DEV 0070 0023  0
2   PRN                  0   0000    17  9077    DEV 0070:0047  0
3   WIN386    SWP  1769472   0020     1  $AAE    C   6506  DPB 0116 13A4  0
4   COURE     FON    23408   0020     1  1F00    C.  2513  DPB 0116 13A4  1

[SFT @ 1014:0000 -- 35 files]
6   SH        EXE    33792   0020     1  1F00    C   1218  DPB 0116 13A4  1
7   VGAFIX   .FON     5360   0020     1  1F00    C   2310  DPB 0116 13A4  1
8   GDI       EXE   275261   0020     1  1F00    C   3037  DPB 0116 13A4  1
```

```
9   SSERIFE  FON        64544   0020     1  1FD0    C   2547  DPB 0116:13A4  1
10  USER     EXE       338406   0020     1  1FD0    C.  3072  DPB 0116:13A4  1
11  WINFILE  EXE       146864   0020     1  1FD0    C.  1794  DPB 0116:13A4  1
12  KEYBOARD DRV         7568   0020     1  1FD0    C:  2301  DPB 0116:13A4  1
13  VGA      3DRV       73200   0020     1  1FD0    C-  2204  DPB 0116:13A4  1
14  COMM     DRV         9280   0020     1  1FD0    C   2253  DPB 0116:13A4  1
15  FILES    EXE        14698   0020     1  1FD0    C: 12643  DPB 0116:13A4  2
16  ANTQUA   TTF        59776   0020     1  1FD0    C-  2947  DPB 0116:13A4  1
[SFT = 1819 0000 -- 30 files]
```

Note WIN386 SWP the SFT entry #3 is the output above. As its name suggests, this is the Windows 386 Enhanced mode swap file Windows uses for disk paging when you don't have a permanent swap file. The SFT entry FLAGS displayed indicates WIN386.SWP's owner is 1AAEh. We can run H2NAME on 8:18 to make sure this all makes sense.

```
D:\UNDOC2>h2name 1aae
Files for 1AAE
 0   >  1   > CON
 1   >  1   > CON
 2   >  1   > CON
 3   >  0   > AUX
 4   >  2 ==> PRN
 5   >  3 ==> WIN386  SWP
 6   > -1
```

Sure enough, the first PSP:1AAEh has a file handle that points back to this SFT entry. Running MEMMAP (see Chapter 7) or MEM /P shows that PSP:1AAEh corresponds to WIN386.EXE.

```
D:\UNDOC2>undmem

1AAD    1AAE    0452 ( 17696)   Env at 1AA2    C:\WIN31\system\win386.exe
```

Do not confuse the word 1AAEh for SFT entries 4–16 in the FILES output. Specifying the number 1AAEh to H2NAME causes it to incorrectly process the message "that's not a PSP." H2NAME cannot check the first word of the specified segment to make sure they are the 0x20CD signature which are the opcode bytes for an INT 20h instruction that begins every PSP.

The problem is that when running H2NAME from within a DOS box, the last column in the FILES output is the virtual machine (VM) ID of the first process. ID 0 indicates files or devices opened before Windows starts. ID 1 indicates the System VM where Windows applications run. 2 indicates the first DOS box. In the test FILES was run within a first DOS box (VM 2). As indicated by the last column of FILES output, the number 1AAEh is only a valid PSP within another virtual machine, VM 1. In fact, this other virtual machine is the System VM in which Windows applications are run and thus PSP:1AAEh is the value stored in the System VM's address space. Because the DOS box happened to have a PSP:1AAEh at the time, the H2NAME test looks valid. As discussed in Chapter 6, when you run a PSP in the System VM it comes from a DOS program run from within WINSTART.BAT, 2 a protected-mode DOS program which grabs memory from other VMs or 3 a Windows application. When you run the WINPSP program from Chapter 3, PSP:1AAEh or the equivalent on your machine shows up plain as day.

```
1FD0    7FF3    KRNL386     3196 0000 (32 files, 1B open)
```

But if the SFT entries for COURIER.FON, SEVENT.FON, VGA3IA.FON and so on all belong to a PSP that is only visible within the System VM, why are these open files located in the global SFT, visible to all processes in all VMs. In other words, why doesn't Windows declare the SFT as instance data. Because, while Windows instances other DOS data structures such as the CDS on a per VM basis,

Windows can't instance the SFT. How else would SHARE work? See the SHARE discussion later in this chapter.)

On the other hand, *parts* of SFTs can be allocated on a per-VM basis. The Windows SYSTEM.INI file's undocumented PerVMFiles= setting that controls how many SFT entries each VM can add to its view of the SFT chain. To support this, the structure pointer in the last SFT table allocated before Windows started up is declared as instance data.

The effect of a PerVMFiles= statement is readily seen in the following output from SFTWALK. Here, CONFIG.SYS said FILES=40, but running the SFTWALK program within a Windows DOS box showed FILES=70:

```
D:\UNDOC2>sftwalk
SFT @ 0116:00CC -- 5 files
SFT @ 1014:0000 -- 35 files
SFT @ 1B19:0000 -- 30 files
FILES=70
```

Thus, Windows implements PerVMFiles= by making an additional SFT table to the end of the chain, just as we saw FILES.COM do for QEMM. (In either case, the DOS FILES= value has been temporarily increased without having to change CONFIG.SYS and reboot.)

Windows's creation of the SFT gets even more complicated because, as noted in Chapter 1 and in the description of DOSGetSFTEntryMax() in Matt Pietrek's *Windows Internals*, KRNL386 does its own expansion of the SFT, independent of PerVMFiles=. When SFTWALK is run as a Windows program (see Chapter 3), the output once again changes:

```
SFT @ 0116:00CC -- 5 files
SFT @ 1014:0000 -- 35 files
SFT @ 319A:0000    87 files
FILES=127
```

In this session, as happened not to have run the QEMM FILES.COM program. If we had, its added SFT would also show up on the SFT chain. As you can see, the SFT was almost ready to be expanded.

The source code for FILES appears as Listing 8-19. Just as SFTWALK did, FILES walks the SFTs. However, FILES also needs to call SFT to get information on each open file. FILES starts with the first SFT pointed to by SysVars. It passes a file's entry in that table, and then goes into a loop following the next-SFT pointer to find the next table whose segment is zero or whose offset is 0FFFFh. Only in-use SFT entries (NUMHANDLES != 0) are shown.

Listing 8-19: FILES.C

```
/*
FILES.C    List all files in DOS System File Table (SFT)
Andrew Schulman, Revised July 1993

real mode DOS: bcc files.c
protected mode Windows: bcc -WS -2 -DWINDOWS files.c \undoc2\chap3\prot.c

This version is substantially different from that published in
the first edition of UNDOCUMENTED DOS:
-- Includes DOS 3.0 file structure, which is not same as 3.1
   (USHORT dir_entry, not BYTE).  Thanks to Neil Rubenking!
-- DOS 2.x, 3.0, 3.1+ structs combined into union, with access
   macros.  This points up the relative inflexibility of structures
   struct.fcb_next just turns into an offset, but at compile-time,
   with no control over changing field offsets at run-time.
-- Replaced previous check for possible orphaned files, which was
   just too flaky.  Now just use simple garbage-collection test:
   for each SFT entry, see if its owner's JFT actually contains a
   reference to this SFT.  You can examine FILES output and decide
   for yourself if these files are really orphaned.  If they are,
```

```
   you can run SFT_FREE with their SFT index # on the command line.
-- Ported code to protected mode Windows (see #ifdef WINDOWS)
-- On suggestion of Geoff Chappell, got rid of AUX-CON "sanity check,"
   which was insane
-- Can be run with -FCB switch to view System FCBs instead of SFTs.
*/

#include <stdlib.h>
#include <stdio.h>
#include <string.h>
#include <dos.h>
#ifdef WINDOWS
#include  windows.h"
#include  prot.h"           // see \undoc2\chap3\prot.h
#endif

typedef unsigned char BYTE;
typedef unsigned short WORD,
typedef unsigned long DWORD,
typedef BYTE far *FP,

#pragma pack(1)

typedef struct file2 {
    BYTE num_handles, open_mode,
    BYTE fattr;     // might be wrong"
    BYTE drive,
    BYTE filename[8], ext[3],
    WORD unknown1, unknown2,
    DWORD fsize;
    WORD date, time;
    BYTE dev_attr;
    union {
        FP dev_drv;         // for CHAR dev
        WORD cluster[2],    // for disk file (BLOCK dev)
        } u,
    //
    // NOTE! no owner_psp!
    } file2; // for DOS 2.x

typedef struct file30 {
    WORD num_handles, open_mode,
    BYTE fattr,
    WORD dev_info,    // includes drive number
    FP ptr,             // device driver (CHAR) or DPB (BLOCK)
    WORD start_cluster, time, date,
    DWORD fsize, offset,
    WORD rel_cluster, abs_cluster, dir_sector;
    WORD dir_entry,    // only difference from file31: WORD, not BYTE
    BYTE filename[8], ext[3];
    DWORD share_prev_sft,
    WORD share_net_machine, owner_psp,
    //
    } file30, // for DOS 3.0 only

typedef struct file31 {
    WORD num_handles, open_mode,
    BYTE fattr,
    WORD dev_info;    // includes drive number
    FP ptr,             // device driver (CHAR) or DPB (BLOCK)
    WORD start_cluster, time, date;
    DWORD fsize, offset,
    WORD rel_cluster, abs_cluster, dir_sector,
    BYTE dir_entry, filename[8], ext[3];
    DWORD share_prev_sft;
    WORD share_net_machine, owner_psp;
    // ...
```

```
    } file31; // for DOS 3.1+

typedef union file {
    file2 f2,
    file30 f30;
    file31 f31;
    } file,

// access macros
#define DOS(maj)                (_osmajor == (maj))
#define DOSVER(maj, min)        (_osmajor == (maj) && _osminor == (min))
#define DOS3_FIELD(pf,x)        (DOSVER(3,0) ? (pf)->f30.x : (pf)->f31.x)
#define DOSVER_FIELD(pf,x)      (DOS(2) ? (pf)->f2.x : DOS3_FIELD(pf,x))
#define FILENAME(pf)            DOSVER_FIELD(pf,filename)
#define EXT(pf)                 DOSVER_FIELD(pf,ext)
#define FSIZE(pf)               DOSVER_FIELD(pf,fsize)
#define FATTR(pf)               DOSVER_FIELD(pf,fattr)
#define NUM_HANDLES(pf)         DOSVER_FIELD(pf,num_handles)
#define DEV_WORD(pf)            DOS3_FIELD(pf,dev_info)
#define DEV_ATTR(pf)            (DEV_WORD(pf) & 0x80)
#define CHAR_DEV(pf)            (DEV_ATTR(pf) == 0x80)
#define DISK_FILE(pf)           (DEV_ATTR(pf)  = 0)
#define DRIVE(pf)               (DOS(2) ? (pf)->f2.drive   DEV_WORD(pf) & 0xDD3F)
#define OWNER_PSP(pf)           (DOS(2) ?  1   DOS3_FIELD(pf,owner_psp))
#define START_CLUSTER(pf)       (DOS(2) ? (pf)->f2.u.cluster[0] : \
                                DOS3_FIELD(pf,start_cluster))
#define PTR(pf)                 DOS3_FIELD(pf,ptr)
#define VM_ID(pf)               DOS3_FIELD(pf,share_net_machine) // Windows VM
#define DEV_DRIVER(pf)          (DOS(2) ? (pf)->f2.u.dev_drv   PTR(pf))
#define DPB pf)                 PTR(pf)

typedef struct sysftab {
    struct sysftab far *next;
    WORD num_files;
    file f[1],
    } SYS_FTAB,

void fail(char *s) { puts(s), exit(1); }

#ifndef MK_FP
#define MK_FP(seg,ofs)  ((FP)(((DWORD)(seg) << 16) | (ofs)))
#endif

#ifdef WINDOWS
#define MAP(ptr, bytes)         map_real((ptr), (bytes))
#define FREE_MAP(ptr)           free_mapped_linear(ptr)
#define GET_REAL(ptr)           get_real_addr(ptr)
#else
#define MAP(ptr, bytes)         (ptr)
#define FREE_MAP(ptr)           /**/
#define GET_REAL(ptr)           (ptr)
#endif

main(int argc, char *argv[])
{
    SYS_FTAB far *sys_filetab, far *next;
    file far *ff,
    char buf[9],
    int size, i, num=0, do_fcbs = 0, orph = 0,

    // either examine SFT tab e or System FCB table (same format)
    int sft_ptr_ofs = 4;
    if (argc > 1 && strcmp(strupr(argv[1]), "FCB") == 0)
        { do_fcbs++; sft_ptr_ofs = 0x1A; }

#ifdef WINDOWS
    WORD mapped;
```

```
    RMODE_CALL r;
    memset(&r, 0, sizeof(r));
    r.eax = 0x5200;
    if (dpmi_rmode_intr(0x21, 0, 0, &r))
    {
        SYS_FTAB far * far *tmp = (SYS_FTAB far * far *)
            MAP(MK_FP(r.es, (WORD) r.ebx + sft_ptr_ofs), 4);
        SYS_FTAB far *psysftab = *tmp;
        FREE_MAP(tmp);
        sys_filetab = (SYS_FTAB far *) MAP(psysftab, 0xFFFF);
    }
    else
        fail("Could not generate real mode 21/5200");
#else
    _asm mov ah, 52h
    _asm int 21h
    _asm add bx, word ptr sft_ptr_ofs   /* either SFT or System FCB chain */
    _asm les bx, dword ptr es:[bx]
    _asm mov word ptr sys_filetab, bx
    _asm mov word ptr sys_filetab+2, es
#endif
    /* DOS box of OS/2 1.x doesn't provide system file tbl */
    if (sys_filetab == (SYS_FTAB far *) -1L)
        fail("system file table not supported");

    /* could try to confirm this size by subtracting one filename
       from another, as Windows does in  "CON CON CON CON CON" code. */
    size   DOS(2) ? 0x28   DOS(3) ? 0x35   0x30,     // SFT entry size

puts("#   Filename            Size   Attr  cRef  Owner   Cluster, DD, DPB");
puts("--  ----------          ----   ----  ----  -----   ----------------");

    do { /* FOR EACH SFT */
        printf("\n[SFT @ %Fp -- %d files]\n",
            GET_REAL(sys_filetab), sys_filetab->num_files);

        /* FOR EACH ENTRY IN THIS SFT */
        ff = (file far *) sys_filetab->f;  // DON'T MAP, already mapped!
        for ( ; i<sys_filetab->num_files; i++, num++, ((FP) ff) += size)
        if (NUM_HANDLES(ff) != 0)   // don't show unused entries
        {
            printf("%-3d ", num);   // SFT index
#ifdef   BORLANDC
            // bcc pmode printf GP faults on non-null-terminated strings
            _fmemcpy(buf, FILENAME(ff), 8), buf[8] = 0, printf("%-8s.", buf);
            _fmemcpy(buf, EXT(ff), 3), buf[3]   0, printf("%-3s  ", buf);
#else
            printf("%-8Fs.",        FILENAME(ff)),
            printf("%-3Fs  ",       EXT(ff)),
#endif
            printf("%10lu ",        FSIZE(ff)),
            printf("%04X\t",        FATTR(ff)),
            printf("%2d   ",        NUM_HANDLES(ff)),
            printf("%04X ",         OWNER_PSP(ff)),

            /* A new check for orphaned files   for each SFT entry,
               see if the entry is referenced in the supposed owner's
               JFT. If it isn't, it's a possible orphan. If the
               reference count (NUM_HANDLES(ff)) is 1, then it's a
               definite orphan! */
            orph = 0;
            if ((_osmajor >= 3) && (NUM_HANDLES(ff) == 1) && (! do_fcbs))
            {
                WORD psp = OWNER_PSP(ff);
                if (*((WORD far *) MK_FP(psp, 0)) == 0x20CD) // real PSP
                {
                    WORD jft_size = *((WORD far *) MK_FP(psp, 0x32));
```

```
                BYTE far *jft = *((BYTE far * far *) MK_FP(psp, 0x34)),
                int i, ok;
                for (i=0, ok=0; i<jft_size; i++)
                    if (jft[i] == num)  // found SFT entry in PSP's JFT
                        { ok++, break; }
                if (! ok) orph++,
            }
        }
        printf( orph? " OR " : "    ");

        if (DISK_FILE(ff))
        {
            printf( %c  ",      'A' + DRIVE(ff)),
            printf("%5u  ",     START_CLUSTER(ff)),
            printf( DPB %Fp",   DPB(ff)),
        }
        else
            printf( DEV %Fp",   DEV_DRIVER(ff)),
        printf(   %d\n", VM_ID(ff)); // Windows VM # (see 2F/1683)
    }

    /* FOLLOW LINKED LIST    */
    next = sys_filetab->next,       // get next.
    FREE_MAP(sys_filetab),          // then free old
    if (next && (FP_OFF(next) != 0xFFFF))
        sys_filetab  (SYS_FTAB far *) MAP(next, 0xFFFF),
    else
        break,
} while (FP_SEG(sys_filetab) &&
         (FP_OFF(sys_filetab) != 0xFFFF)); /* ...UNTIL END */

#ifdef WINDOWS
    if (mapped = get_mapped()) != 0)
        printf("ERROR!  %u mapped selectors remaining!\n", mapped),
#endif
    return 0,
}
```

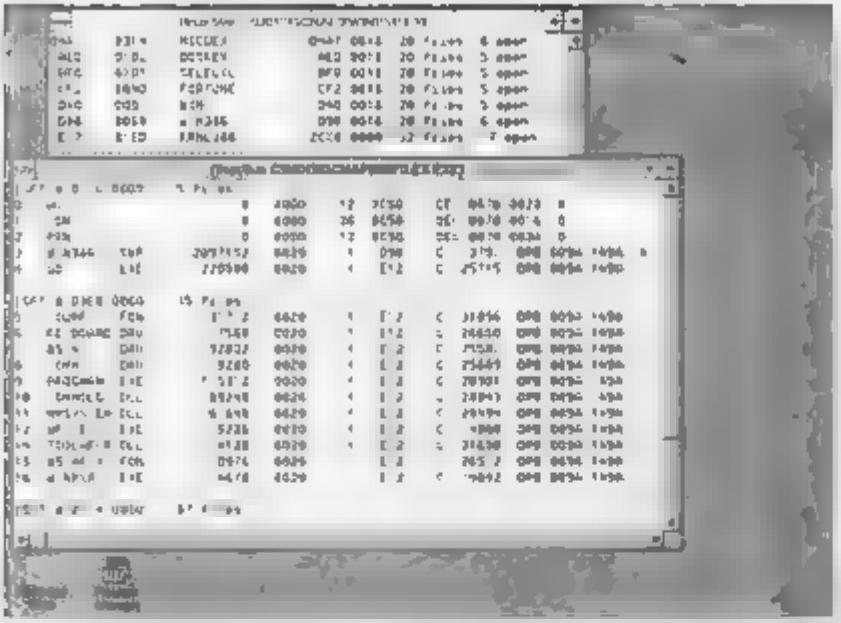
FILES.C would be a much shorter program if there were only one SFT entry structure. Most of the complexity in the program comes from the differences between SFT entries in DOS 2.0, DOS 3.0, DOS 3.1, and higher. Most of these differences are disguised by a set of access macros so that the programmer can, for example, get the name out of a SFT entry with the simple looking expression FILENAME(ff), which, behind the scenes, expands into

```
( osmajor    2) ? ff->f2.filename   (osmajor == 3 && osminor == 0) ?\
   ff->f30.filename   ff->f3).filename
```

FILES.C also uses access macros to make it appear as if the SFT entry has a field containing the drive number for the open file. In fact, the SFT only contains a drive number in DOS 2.x or in DOS 3.0 and higher if bit 31 in a device information word (from which the DRIVE() macro extracts the drive number).

One other reason for FILES.C's length is that you can compile it for protected mode Windows as well as for real mode DOS. Using PROTO.C and PROTO.H from Chapter 3 and a library such as Microsoft's QuickWin or Borland's EasyWin, FILES can run as a Windows program in the System VM, as shown in Figure 8-4. In FILES.C, the map_real_get_real_addr() and free_mapped_near() functions from PROTO.C have been hidden behind yet another set of macros: MAP(), GET_REAL() and FREE_MAP(). These macros have no effect when WINDOWS is not defined, just as when compiling for a real mode DOS. This reduces the #ifdef WINDOWS preprocessor statements that would otherwise clutter up FILES.C even worse than it is now.

Figure 8-4: WINPSP and the Windows version of FILES



Since the SFTs and instanced FILES running as a Windows program in the System VM shows essentially the same output as FILES running in a DOS box. The only difference is in the final (usually empty) SFT table, added in a DOS box by PerVMFiles and in the System VM by the GrowSFTToMaxFiles code in KRNL386.

Releasing Orphaned File Handles

One other thing we can do with FILES is use it to locate possible orphaned files. DOS closes all open files that belong to a process that terminates with INT 21h function 4Ch. However, the common practice of redirecting output from a TSR's installation code to the NUL device normally leaves behind one orphaned file in the SFT. FILES attempts to identify these and displays an "OR" orphan after the owner.

```
C:\UNDOC2\CHAP8> .\chap9\tsrmem > nul

C:\UNDOC2\CHAP8>files

 #  Name
0   AUX                    0    0000      8   9077    DEV 0070:0035
1   CON        .           0    0000     23   9077    DEV 0070:0023
2   PRN        .           0    0000      8   9077    DEV 0070:0047
3   NUL        .           0    0000      1   1289 OR DEV 0116 0048

C:\UNDOC2\CHAP8>udmem | \dos\find "1289"
1288    1289    0094 (  2368)   Env at 1323    C:\COMMAND.COM  C:\C22 23 24 2E 3
1322    1289    0010 (   256)
```

Following the TSR's NUL there is an SFT entry #3 for NUL, with one owner, PSP 1289h. FILES has marked this with an OR, indicating a possible orphan. Running UDMEM from Chapter 7 indicates that PSP 1289h is COMMAND.COM. There is nothing intrinsically wrong with this. A command shell can legitimately own open files, a point that was missed in the first edition of *Undocumented DOS*; a good example is 4DOS.COM, which in disk swapping mode keeps open a swap file.

However, in this case, NUL is definitely an orphaned file. COMMAND.COM opened NUL to support the redirection of the TSR's output. Redirected files have two owners; see Chapter 10 for a description of how command.com shells provide I/O redirection. That NUL here has only one owner (COMMAND.COM) is a clue to tip off that the other party in the redirection hasn't exited. It's worth noticing here that it's COMMAND.COM, not the TSR, that's the file's single owner; as the first edition of *Undocumented DOS* hopelessly confused this point.

While the SFT contains an entry for NUL pointing back at PSP 1289h, running the H2NAME program on PSP 1289h shows that this PSP's JFT has no entry pointing to this SFT entry:

```
D:\UNDOC2>h2name 1289
Files for 1289
 0 ==>  1 ==> CON
 1 ==>  1 ==> CON
 2 ==>  1 ==> CON
 3 ==>  0 ==> AUX
 4 ==>  2 ==> PRN
 5 ==> -1
```

Sure enough, nothing in the presumed owner's JFT points to this SFT. This is how FILES.C attempts to locate orphaned files. As you saw earlier, not every SFT entry has an owner, which appears to FILES.C to be a legitimate PSP but for those that do, FILES.C checks whether the owner's JFT contains a pointer back at this SFT entry. If this SFT entry cannot be reached from the presumed owner's JFT, and if the SFT entry's reference count NUMHANDLES still > 0, it indicates that the entry is garbage.

You can collect this garbage by specifying the (hopefully) orphaned SFT entry number on the command line of our next program, SFT_FREE:

```
C:\UNDOC2\CHAP8>files | \dos\find " OR "
3   NUL     .                0   0000     1  1289 OR DEV 0116,0048

C:\UNDOC2\CHAP8>sft_free 3

C:\UNDOC2\CHAP8>files
...
0   AUX     .                0   0000     8  9077    DEV 0070 0035
1   CON     .                0   0000    23  9077    DEV 0070 0023
2   PRN     .                0   0000     8  9077    DEV 0070 0047
```

All gone! Use this program with extreme care!

The code for SFT_FREE.C (Listing 8-20) is amazingly simple. Once the program gets a pointer to the SFT entry it wants to free, it simply smacks a 0 into its first WORD. As seen in the structures in FILES.C (Listing 8-19), the first WORD of an SFT entry is num_handles, setting this reference count to 0 (except when it's changing anything else, effectively frees up the entry for reuse by DOS.

Listing 8-20

```
/*
SFT_FREE.C -- Free SFT entries specified on command line -- DANGER!!
To find SFT numbers, run FILES and look for 'OR' after the owner PSP
Andrew Schulman, July 1993
*/

#include <stdlib.h>
#include <stdio.h>
#include <string.h>
#include <dos.h>

typedef unsigned char BYTE;
typedef unsigned short WORD;

typedef struct _sft {
    struct _sft far *next;
```

```
    WORD num;
    WORD file,  // SFT entries start here; num_handles is first entry
    // other stuff not used here
    } SFT,
void fail(const char *s) { puts(s); exit(1), }

main(int argc, char *argv[])
{
    BYTE far *sysvars,
    SFT far *sft,
    int curr_handle, handle_to_free, size, i, files, testing,

    if (argc < 2)
        fail( usage: sft free [ testing] [list of SFT handles to free!'] ),

    _asm mov ah, 52h
    _asm int 21h
    _asm mov word ptr sysvars+2, es
    _asm mov word ptr sysvars, bx
    if (! sysvars)
        fail("can't get SysVars"),

    #define DOS(maj) (_osmajor == (maj))
    size   DOS(2) ? 0x28   DOS(3) ? 0x35 : 0x3B,     // SFT entry size

    sft = *((SFT far * far *) &sysvars[4]),
    if ((! sft) || (sft == (SFT far *) -1L))
        fail("can't get SFT");

    // walk through SFT chain once to find FILES= value
    files = 0,
    while (FP_OFF(sft) != 0xFFFF)
    {
        files += sft->num,
        sft = sft->next,
    }
    if ((! files) || (files > 255))
        fail( Something wrong' ),

    testing   0,
    if (stremp(strupr(argv[1]), "-TESTING") == 0)
        { testing++; argv++; argc--; }

    for (i=1; i<argc; i++)
    {
        if ((handle_to_free = atoi(argv[i])) > files)
            fail("invalid SFT entry specified'"),
        curr_handle = 0,
        sft = *((SFT far * far *) &sysvars[4]);
        while (FP_OFF(sft) != 0xFFFF)
        {
            if (handle_to_free < (curr_handle + sft->num))
            {   // one we want to free is in this SFT
                BYTE far *sft_entry = (BYTE far *) &sft->file;
                WORD far *num_handles;
                sft_entry += ((handle_to_free - curr_handle) * size);
                num_handles = (WORD far *) sft_entry,   // first item
                if (testing)
                {
                    if (*num_handles != 0) fail("already in use!");
                    *num_handles = 1;       // create phony used entry
                    // should create full-blown orphaned entry'
                }
                else
                {
                    if (*num_handles == 0) fail("already free'");
                    *num_handles = 0;           // free it'
```

```
                // should check owner JFT to make sure really orphan!
            }
            break;
        }
        curr_handle += sft->num;
        sft = sft->next;
    }
}

return 0;
}
```

SET_ERLEV should not be necessary with the TSRs produced using the TSR skeleton in Chapter 9. As noted there, the actual test for correct TSR deinstallation is the freeing up of any otherwise orphaned file handles. The generic TSR in Chapter 9 deinstalls with a normal DOS terminate (INT 21h function 4Ch), thereby eventually closing and freeing any open file handles.

More File Handles

You've seen that the handle-based file I/O routines introduced in DOS 2.0 rely on two data structures, the system-wide linked list of System File Tables and the per-process Job File Table. In contrast to the older File Control Blocks (FCBs), which applications allocated on an as-needed basis, the SFTs and each JFT are normally allocated by DOS itself and therefore are limited in size. You've seen that the FILES statement in CONFIG.SYS governs the number of files built in the SFTs. Normally, there are 20 possible open file handles in a process' JFT. This is dictated by the fact that a 20-byte JFT resides directly inside the PSP. This is the downside to the switch from FCBs to handles/SFTs.

DOS 3.3 introduced a function, Set Handle Count (INT 21h, AH=67h), which can increase the size of the calling process' JFT, thereby increasing the files and devices that may simultaneously be opened using handle-based File I/O. Several mass-programmers claim the function "doesn't work" (never because they've forgotten to increase the FILES setting before attempting to keep 50 files open at once), or because they think that calling this function automatically allows them to open more files with a certain brand of network software. See "FILES" vs. File Handles" earlier in this chapter. In fact, while these supposed bugs are nothing more than coding errors.

However, as indicated, there are specific cases for INT 21h, AH=67h. Note, too, several bugs in this function. In the version 3.3 code, as used in *Ralf Brown's Interrupt List* (Ralf Brown, April 1988), note that the function can incorrectly locate data too much memory because its code uses an RCR instruction instead of the correct RCR.

Fortunately, it's just as easy to perform the same function ourselves. Since a JFT is embedded directly at offset 18h in the PSP, it seems like it should be possible to increase its size. However, since DOS 3.0+ the PSP has also contained a far pointer to the JFT and to a word holding its size. The relevant fields in the PSP, which we already used in the orphan-seeking code, are:

```
18h   20 BYTEs  DOS 2+ JFT
32h   WORD      DOS 3+ max open files
34h   WORD      DOS 3+ JFT address
```

You can't directly change the size of the array at offset 18h in the PSP, but you can allocate a new, larger block of memory for the JFT, bump up the count at offset 32h in PSP, copy the old table into the new one, and then set the pointer at offset 34h to the new table. The same is true of manipulating the possibly several other seemingly static DOS arrays, such as the SFTs and CDS, whose far pointers are located in SysVars.

The program at Listing 8.21, HANDLE.C, carries out this series of operations. HANDLE takes a number on its command line and attempts to resize its own JFT.

```
D:\UNDOC2>fhandle 40
Currently 20 max JFT file handles
And SFT FILES=40
Max file handles increased to 40
Opened 34 files
```

To test that more files can be opened, FHANDLE continually opens its own executable file (argv[0]) in a loop until the Microsoft C _dos_open() function fails.

Listing 8-21: FHANDLE.C

```
/*
FHANDLE.C
Alternative to using INT 21h function 67h (added in DOS 3.3)
Andrew Schulman, revised July 1993

bcc fhandle.c
fhandle 40
fhandle 40 -testing

NOTES
-- Generally need FILES= greater than 20 in CONFIG.SYS to have any
   effect.  Actually, this isn't strictly necessary.  Certainly you
   could have a larger JFT than your SFT and have multiple JFT
   entries pointing to the same SFT entry.  This occurs already,
   where normally file handles 0, 1, and 2 all correspond to
   SFT entry 0 (CON).  But this generally isn't why programmers want
   to increase their JFT size.  So, if your intended JFT size is
   larger than the current SFT size, you can:
-- Change FILES= in CONFIG.SYS and reboot.
-- Or use Quarterdeck FILES.COM program to increase SFT size.
-- Or see XLASTDRV program in Chapter 2, which expands DOS, and adopt
   it to expand the SFT chain.
-- If you want to open >20 files simultaneously with high-level functions
   like fopen(), you probably must increase run-time library tables.  For
   example, in Microsoft C the size of table for FILE* is hard-wired
   to 20 in \mc\source\startup\_file.c (#define _NFILE_ 20).  So
   increase the size of this table as well (and recompile
   startup.obj) if you want to use >20 fopen() at once, even after
   using the following code.
*/

#include <stdlib.h>
#include <stdio.h>
#include <string.h>
#include <dos.h>

typedef unsigned char BYTE;
typedef unsigned WORD;
typedef unsigned long DWORD;
typedef BYTE far *FP;

#ifndef MK_FP
#define MK_FP(seg,ofs)  ((FP)(((DWORD)(seg) << 16) | (ofs)))
#endif

extern unsigned files(void);    // in TFTF.C

void fail(char *s) { puts(s); exit(1); }

typedef struct _sft {
    struct _sft far *next;
    WORD num;
    // other stuff not used here
    } SFT;

WORD files(void)
{
    SFT far * far *sysvars; // treat SysVars as array of far ptrs
```

```
    SFT far *sft;
    WORD files = 0;

    _asm mov ah, 52h
    _asm int 21h
    _asm mov word ptr sysvars+2, es
    _asm mov word ptr sysvars, bx

    if (! sysvars) return 0;
    for (sft = sysvars[1]; FP_OFF(sft) != 0xFFFF; sft = sft->next)
        files += sft->num;
    return files;
}

main(int argc, char *argv[])
{
    WORD far *pmax = (WORD far *) MK_FP(_psp, 0x32);
    BYTE far * far *pjft = (BYTE far * far *) MK_FP(_psp, 0x34);
    BYTE *new_jft;
    WORD max = *pmax;
    WORD new_max;
    int f, i;

    if (argc < 2)
        fail("usage: fhandle [-testing] [#handles]");
    new_max = atoi(argv[1]);
    printf("Currently %u max JFT file handles\n", max);
    printf("And SFT FILES=%u\n", files());

    if (new_max <= max)
        fail("nothing to do");
    else if (new_max > files())
        fail("FILES= too low  edit CONFIG.SYS and reboot\n"
             "or run a program like DEMM FILES.COM to grow the SFT");

    if (! (new_jft = (BYTE *) malloc(new_max)))
        fail("insufficient memory");
    _fmemcpy(new_jft, *pjft, max);              // copy over old entries
    _fmemset(new_jft+max, 0xFF, new_max - max); // fill in new entries
    *pmax = new_max;                            // set new max file handles
    *pjft = (BYTE far *) new_jft;               // set new JFT

    printf("Max file handles increased to %u\n", new_max);

    // now test how many files we can open by opening ourselves (argv[0])
    for (i=0; ; i++)
        if (_dos_open(argv[0], 0, &f) != 0)
            break;
    printf("Opened %d files\n", --i);

    if (argc > 2 && stremp(strupr(argv[2]), "-TESTING") == 0)
    {
        BYTE cmd[16];
        // printf("Closing %d ==> %d\n", f, new_jft[f]);
        _dos_close(f);  // close last one so we can spawn shell
        sprintf(cmd, "H2NAME %04X", _psp);
        printf("\n> %s\n", cmd);     // show command line
        system(cmd);                 // run H2NAME on my PSP
        printf("\n> FILES\n");
        system("FILES");             // run FILES
    }

    return 0;
}
```

If FHANDLE is also run with the -TESTING command line option, it runs the previous H2NAME (Listing 8.18) and FILES (Listing 8.19) programs. First it closes the most recently opened file so that there is a free JFT entry from which to spawn the programs. Next it runs FHANDLE and

sometimes has problems spawning H2NAME and FILES. This not only helps verify that you can really open more files, but also helps to show how these three different programs tie together:

```
D:\UNDOC2>fhandle 40 -testing
Currently 20 max JFT file handles
And SFT FILES 40
Max file handles increased to 40
Opened 34 files

> H2NAME 6C7B
Files for 6C7B
 0 ==>  1 ==> CON
 1 ==>  1 ==> CON
 2 ==>  1 ==> CON
 3 ==>  0 ==> AUX
 4 ==>  2 ==> PRN
 5 ==>  3 ==> FHANDLE EXE
 6 ==>  4 ==> FHANDLE EXE
;     etc
37 ==> 35 ==> FHANDLE EXE
38 ==> 36 ==> FHANDLE EXE
39 ==> -1

> FILES
#   Filename              Size   Attr  cRef  Owner   Cluster, DD, DPB
--  --------              ----   ----  ----  -----   -----------------

[SFT @ 0116:00CC -- 5 files]
0   AUX                      0   0000    10  9077    DEV 0070 0035
1   CON                      0   0000    29  9077    DEV 0070 0023
2   PRN                      0   0000    10  9077    DEV 0070:0047
3   FHANDLE  EXE          9126   0020     1  6C7B    D: 30714  DPB 0FF1:0000
4   FHANDLE  EXE          9126   0020     1  6C7B    D  30714  DPB 0FF1 0000

[SFT @ 1014:0000 -- 35 files]
5   FHANDLE  EXE          9126   0020     1  6C7B    D  30714  DPB 0FF1:0000
6   FHANDLE  EXE          9126   0020     1  6C7B    D  30714  DPB 0FF1 0000
; ... etc. ...
36  FHANDLE  EXE          9126   0020     1  6C7B    D  30714  DPB 0FF1:0000
```

You might wonder why there are all those SFT entries for the same file. From the FILES output, they all look identical. However, one of the fields in the SFT not shown by FILES is the current file position. This value cannot be shared among multiple opens of the same file, since the following code (for example) is valid:

```
int f1 = open("foo.bar", O_RDONLY);
int f2 = open("foo.bar", O_RDONLY);
lseek(f1, 10, SEEK_CUR);
lseek(f2, 20, SEEK_CUR);
```

The f1 and f2 handles must lead to separate SFT entries. Even loading SHARE can't change this, assuming the second open() is allowed to succeed.

Once again, increasing the DOS file handles does not automatically allow you to open more files with the fopen() function in C. If you need to increase the number of fopen'able files, consult your compiler's startup code. For example, in Microsoft C you can increase the FILE* maximum by changing the value of _NFILE_ in the startup code (see STARTUP\CRTDATA.ASM).

Note that inheritance is not inheritable, so FHANDLE can't pass its increased wealth along to any children it might have. For an in-depth look at this topic, see the article, "DOS File Handle Limits" by David Burk, *HHCP Specialist* (February 1993; this magazine is now the *Windows/DOS Developer's Journal*).

System FCBs

And now for a trip down memory lane

So far we have seen how handle-based DOS file operations manipulate SFTs. But remember DOS File Control Blocks inherited from CP/M when it was the standard of the 8-bit microcomputer world? How does DOS handle FCBs as it were? FCBs. Recall keeping some nausea medicine nearby how FCBs work. Instead of getting back a handle when a call to the operating system to open a file, an application creates an FCB *in its own data area* and tells the operating system where this FCB is. DOS stores the FCB in the application's data area.

Thus the application allocates FCBs on behalf of the operating system—rather than the other way around. Such file-processors were keeping critical operating system data in the application's data area should be rather obvious. For example, whereas today's DOS can close any open files when an application exits in the days of FCBs the operating system couldn't do anything about programs that left behind open files when exiting.

Furthermore, putting the FCB under the application's control meant that every application using FCBs was dependent on its precise structure. Contrast the way that, for example, the vast majority of DOS applications are not dependent on the structure of an SFT. The dependence of applications on the FCB structure has obviously made it impossible to change this structure even when necessary. For instance, to support media larger than 32 megabytes. FCBs in fact are a perfect example of why it is bad to expose operating system internals to applications'.

What is less obvious is that there was one benefit to FCBs over the new, improved handle-based file functions. Since the application allocates FCBs there are practically unlimited open files. An FCB system doesn't need a FILES setting in CONFIG.SYS. When the application needs to open a file it creates another FCB.

SFTs and file handles were introduced in DOS 2.0, and with them the need for a FILES setting so that users could exercise some control over the trade-off between having lots of potential open files on the one hand and taking too much precious memory on the other.

However, Microsoft couldn't get rid of FCBs entirely. While over time Microsoft has reduced its support for FCBs (for example, the Windows DOS extenders—the MS-DOS programmer's reference continues to document the FCB calls while considering them as superseded. According to Microsoft, programmers "should not use a superseded function except to maintain compatibility with versions of MS-DOS earlier than version 2.0.")

Surprisingly, Microsoft still continues to use FCBs even in parts of DOS 5.0 and 6.0 that presumably do not require compatibility with DOS 1.0. Microsoft seldom follows its own advice; this advice is intended, apparently, for everyone else. For example, a simple INTRSPY script reveals that COMMAND.COM extensively uses FCBs. (Curious? It uses function 29h—FCB Parse Filename—as part of its normal operation. It uses FCB 1 and 2 and 2nd FCB 2 to Search for the PATH command, perhaps as a clever way to get starting cluster values. It uses function 1Bh—FCB Device Info for DIR and function 21h—FCB Read for BAT with wildcards. Additionally, extended FCBs are necessary to change volume labels in pre-DOS 4.0 disks; disks formatted under DOS 4.0 or higher can have their volume labels changed or created via Media ID generic IOCTL calls mentioned earlier.)

So how does DOS continue to support FCBs without totally compromising the system? By gathering several System FCBs. When a program uses FCBs DOS copies all pertinent information from the program's own FCB to an available System FCB. DOS does the actual work using the System FCB, and then copies the information back into the user's original FCB before returning control. Programs using FCBs do not have to know of System FCBs.

Some FCBs do not use the application's System FCB sounds like a lot of work. However, System FCBs are not SFTs; they're smaller. The layout for System FCBs and SFTs is identical. This is the reason DOS functions that work with SFT entries work exactly the same way with System FCBs. The only differences are that System FCBs are kept on a separate list from the SFTs that DOS for

pointer to the System FCB chain is at a different location in SysVars from the SFT pointer and that DOS must keep a System FCB synchronized with the old FCB that its owner believes is controlling access to a file. SysVars[0x10] determines the number of SFT entries, so FCBS= determines the number of System FCBs.

That System FCBs are SFTs in disguise makes it easy to use our SFT walking programs to view System FCBs. If the symbol DOS_FCBS is enabled, SFTWALK (listing 8.17) can determine the value of FCBS= by walking the chain of System FCBs, just as it determines the value of FILES= by walking the SFT chain:

```
D:\UNDOC2>sftwalk
SFT @ 0116:00CC -- 5 files
SFT @ 1014:0000 -- 35 files
FILES=40
System FCB table @ 1979:0000 -- 8 files
FCBS=8
```

The only difference in the SFT walking code is that SysVars[0x10], rather than SysVars[4], is consulted:

```
printf("FILES=%d\n", sftwalk[4],     "SFT"),
printf("FCBS=%d\n",  sftwalk[0x1A], "System FCB table"),
```

SYSTEM.EXE (Extra 8.19) takes an optional FCBS switch on its command line.

The problem with System FCBs, however, is that because the FCBS statement in CONFIG.SYS limits the number of System FCBs, programs can no longer open unlimited FCBs. Once the System FCBs are used up, DOS starts to close the least recently used System FCBs. There was a complicated workaround for this in IBM's DOS 4.0 that involved protected FCBs, the very FCBS=x,y statement that was dropped in DOS 5.0.

While this causes a lot of extra work just to support a archaic manner of opening files, it does protect those programs that use the older calls to coexist with the newer techniques. Hard to believe, but right now many programs still use FCBs for one reason or another. System FCBs give DOS the control it needs to share files, network, and multitask users while still allowing ancient programs to run without change.

One last reason to care about System FCBs is that a heavily encrypted piece of code in Windows 3.1 Enhanced mode VxD code uses the offset of the first System FCB header as part of its test for genuine MS-DOS. Via a series of DOS calls which this offset is non-zero (that is, LIN ODE SysVars[0x1A] != 0), Microsoft considered a competitor's DOS and certain versions of Windows issue a non-fatal error message. Chapter 3 discusses this in great detail; see MSD.EXE in Chapter 10.

The SHARE Hooks

In our long discussion of the DOS file system you may have been wondering where SHARE fits in. How does the SHARE.EXE TSR portion tack itself into the DOS file system?

If you've been through the appendix to this book, you will see many, many references to SHARE. Far more than one would expect from what seems like a fairly simple file sharing and record locking subsystem. While the network redirector interface that we describe next is no model of software engineering compared to SHARE, it seems downright elegant.

While SHARE provides a small set of API functions, some documented, using INT 2Fh AH=10h and INT 2Fh AH=52h, AH=10h is not its primary mode of operation. Instead, SHARE patches itself into the DOS kernel.

The DOS kernel makes calls using far pointers at various significant times during execution. These pointers, known as the SHARE hooks, are located at negative offsets from the first SFT. By default, the SHARE hooks point at one of two dummy routines which merely set or clear the carry flag, depending on whether the function should succeed or fail when SHARE is not loaded. SHARE

changes these pointers to transfer control to its own routines. As a result of SHARE's modifications to the DOS kernel, most TSR or other programs can't remove SHARE. DOS will hang the next time it tries to call one of the SHARE functions through the no longer valid pointers.

SHARHOOK.C (Listing 9-22) is a simple program to dump out the SHARE hooks. Usually more interesting than the SHARHOOK output tells you whether SHARE is installed because prior to loading SHARE, all the hooks point to the same two routines; after loading SHARE, each hook points to a different location which can of course be disassembled.

```
C:\UNDOC2\CHAP8>sharhook
-3c     0116 0090   FDC8 44AA   unknown
-38     0116 0094   FDC8:44AE   OpenFile
-34     0116 0098   FDC8:44AE   CloseFile
; ...
-c      0116 00C0   FDC8:44AE   CloseFileIfDup
-8      0116 00C4   FDC8 44AA   Close?
-4      0116 00C8   FDC8:44AA   UpdateDirInSFT

C:\UNDOC2\CHAP8>share
SHARE installed

C:\UNDOC2\CHAP8>sharhook
-3c     0116 0090   0000:0000   unknown
-38     0116 0094   1842:0954   OpenFile
-34     0116 0098   1842:0958   CloseFile
; ...
-c      0116:00C0   1842:0980   CloseFileIfDup
-8      0116:00C4   1842:0984   Close?
-4      0116 00C8   1842 0988   UpdateDirInSFT
```

Listing 8-22: SHARHOOK.C

```
/*
SHARHOOK.C -- Dump DOS SHARE hooks
Andrew Schulman, June 1993
*/

#include <stdlib.h>
#include <stdio.h>
#include <dos.h>

typedef void (far *FUNCPTR)(void);

char *share_func_name[] = { "unknown", "OpenFile",  CloseFile",
    "CloseAllMachine",  CloseAllProcess",  "CloseByName",  LockRegion",
    "UnlockRegion",  CheckRgnLocked", "GetOpenFileListEntry",
    "update FCB from SFT?", "get first cluster of FCB?", "CloseFileIfDup",
    "Close?", "UpdateDirInSFT" };

main()
{
    unsigned char far *sftptr;
    FUNCPTR far *sharehooks, far *hook;
    int ofs, i;

    _asm mov ah, 52h
    _asm int 21h
    _asm les bx, dword ptr es:[bx+4]
     asm mov word ptr sftptr+2, es
     asm mov word ptr sftptr, bx

    sharehooks = (FUNCPTR far *) (sftptr - 0x3c);
    for (i=0, hook=sharehooks, ofs=0x3c, i<15, i++, hook++, ofs-=4)
        printf("    %4x    %Fp    %Fp    %s\n",
            ofs, hook, *hook, share_func_name[i]);
    return 0;
}
```

The three most important SHARE hooks are those called when a file is opened, closed, and modified. Additional hooks are used to pass through several undocumented DOS calls for closing files by process and server, by name, locks and unlocks regions of a file for checking whether a region is locked, as well as two hooks whose use is not entirely known. All of the SHARE hooks are listed in the appendix under INT 2Fh function 52h.

When a request to open a file DOS first canonicalizes the filename. After determining that there are file handles available, the caller's PSP and allocating an SFT entry, DOS then calls the SHARE hook to open a file. DOS calls through whatever function pointer is pegged at offset 38h from the start of the DOS SFT. If this hook returns with carry set, the file is not available due to sharing violations, so DOS deletes and frees the SFT entry, returning an error. If the sharing retry count is exhausted or the hook returns with carry clear, SHARE proceeds by beginning a DOS critical section, checking whether the file can be opened legally in the SHARE records of the SFT entry, second, finally ending the critical section. The determination of whether the file may be opened SHARE searches its list of open files for a matching record. If a matching file entry is found, the two open modes of the new open of the file and the existing open are compared according to the standard SHARE rules. For example, an open for Write locks out a subsequent open Read/Write if no match is found, a new sharing record is created for the new file and the open is allowed to succeed. When closing a file SFT fields, SHARE stores, among other things, the file's owner and links the SFT to any SFTs already open creating the same file.

When a file is closed, DOS again calls on SHARE. After beginning a DOS critical section, SHARE removes any locks placed on the file by the calling process and unlinks the SFT entry from the chain of SFT entries for the file, if the close removes the final reference to the file, SHARE frees the SFT entry. Finally, SHARE ends the DOS critical section. If the SFT entry destroyed was the last reference to the file, SHARE also erases the sharing record for that file.

DOS calls two of the SHARE most important SHARE hooks when it sees the file size or time stamp changed. DOS tells or SHARE to propagate these changes as well as any changes in the starting cluster and the first byte of the SFT. SHARE updates the sharing records that all processes have a consistent view of the file, especially the starting cluster and file size. You can see an interesting result of this code by writing to a file under a multitasker. From another Windows session, the file appears to grow in spurts as the operating system flushes its disk cache, even though its directory entry still shows a zero-length file. Provided that the second program reads until DOS returns a zero in the number of bytes read rather than using the size in the directory entry.

It is important to use SHARE when running a preemptive multitasking system such as Windows Enhanced mode. For SHARE to maintain file locks for multiple Windows VMs, you must run it *before* Windows. Running SHARE from within a Windows DOS box is a bad idea as Microsoft prevents you from doing so.

Unfortunately, Microsoft prevents users from running SHARE in a Windows DOS box by *preloading* it. If SHARE is already installed when Windows is loaded, before Windows, the SHARE detection INT 2Fh/AX=1000h call succeeds under Windows. This information hinders Windows from loading SHARE or that Windows contains built-in support for SHARE. Versions of Windows for Workgroups 3.11 and in Chicago Windows *does* contain support for SHARE in form of the VSHARE.386 VxD. In fact, Windows just wants to see if you have loaded SHARE from DOS before. By hooking the INT 2Fh SHARE detection call, Windows mistakenly loads the DOSMGR.VxD built into WIN386.EXE, takes SHARE.EXE into account, installing. SHARE.EXE makes this INT 2Fh call, sees that SHARE is supposedly already installed, and exits. DOSMgr passes the same INT 2Fh check, installed with the VMM function Hook V86 Int Chain to emulate the correct ENTER OPEN and NESTED.

You can run SHAREBOOK under Windows to confirm whether SHARE is really installed or not.

```
C:\UNDOC2\CHAP8>share
SHARE already installed

C:\UNDOC2\CHAP8>sharbook
-3c     0116,0090   FDC8:44AA   unknown
-38     0116 0094   FDC8 44AE   OpenFile
-34     0116 0098   FDC8 44AE   CloseFile
-30     0116 009C   FDC8:44AA   CloseAllMachine
-2c     0116 00A0   FDC8:44AA   CloseAllProcess
-28     0116 00A4   FDC8 44AA   CloseByName
; -
```

That tells two different hook functions are installed as a sure tip off that SHARE is *not* already installed. Again, none of this applies under VSHARE 386.

Microsoft's DOS programmer's reference explicitly mentions the fake SHARE problem: "Some operating environments such as Windows intercept this multiplex interrupt and always return a nonzero value, no matter whether the Share program is loaded or not." It is sick when due to the manufacturer's own actions you can't use a function labeled Get SHARE.EXE Installed State to get the SHARE installed state.

However, Microsoft does recommend a true SHARE detection method: "To determine whether file sharing is available, a program should check for error values upon returning from carrying out a file sharing function such as Lock, Unlock, Unlock, Interrupt 21h Function 5Ch." It would be nice if PC diagnostic programs would heed this advice rather than blindly reporting "SHARE installed" under Windows. The code in Listing 8.23, IS_SHARE.C, presents both the now bogus SHARE detection call and one that actually works, based on function 5Ch.

Listing 8.23: IS_SHARE.C

```
/*
IS_SHARE.C -- Determine if SHARE really loaded
Andrew Schulman, April 1993
*/

#include <stdlib.h>
#include <stdio.h>
#include <dos.h>

int bogus_share(void)
{
    unsigned char bogu;
    _asm mov ax, 1000h
    _asm int 2fh
    _asm mov bogu, al
    return (bogu == 0xff);
}

int is_share(void)
{
    _asm push si
    _asm push di
    _asm xor bx, bx
    _asm mov cx, bx
    _asm mov dx, bx
    _asm mov si, bx
    _asm mov di, bx
    _asm mov ax, 5C00h      /* try to lock */
    _asm int 21h
    _asm jc lock_error
have_share:
    _asm mov ax, 5C01h      /* SHARE there: unlock! */
    _asm int 21h
    _asm pop di
    _asm pop si
    return 1;
```

```
lock_error:
    _asm pop di
    _asm pop si
    _asm cmp ax, 1          /* invalid function: no SHARE */
    _asm  ne have_share_2
no_share
    return 0;
have_share_2:
    return 1;
}

main(int argc, char *argv[])
{
    int share = is_share();
    if (bogus_share())
        puts( share ? "SHARE loaded"
              "SHARE supposedly loaded, but it really isn't" );
    else
        puts( share ? "SHARE supposedly not loaded, but Func 52h present" :
              "SHARE not loaded" );
    return 0;
}
```

In a Windows DOS box unless SHARE was run before starting Windows IS SHARE displays the message "SHARE supposedly loaded, but it really isn't."

Microsoft's VSHARE.386 takes this profession a thing of the past. As part of its major Chicago project—DOS 7.0 and Windows 4.0—Microsoft is moving many possible all pieces of MS-DOS provided by SHARE.EXE into Windows/386. Like most such virtual device drivers (see Chapters 1 and 3), Microsoft is providing some of these VxDs (including VSHARE.386) as part of Windows for Workgroups 3.11 prior to the release of Chicago. VSHARE.386 provides file sharing and locking without having to load SHARE before Windows. Because it's a VxD, VSHARE also does not waste conventional memory—VxDs use 32-bit protected-mode code allocated out of extended memory. With a DEVICE=VSHARE.386 statement in SYSTEM.INI, when Windows reports that SHARE services are available, they actually will be. What a concept!

The MS-DOS Network Redirector

As we've seen, MS-DOS contains a set of 6 function pointer hooks that are set by SHARE.EXE and that MS-DOS calls if it encounters sharing violations (Int 2Fh, AX=1000h). Another set of hooks in MS-DOS is the network redirector interface. Whereas DOS calls SHARE through function pointers with a far CALL, DOS calls network redirectors with INT 2Fh, AX=1100h. Again, whereas SHARE requires setting the value of function pointers in the DOS kernel, writing a redirector requires hooking INT 2Fh.

Not to be confused with Int 21h redirection (see Chapter 10), the MS-DOS network redirector is a mechanism for inserting a routine into the stream of file system and printer requests so that some requests can be carried out and serviced in a special way. Generally, a redirector services such requests by turning them into network packets sent to a file server, but there's nothing in the redirector mechanism that restricts it to network software. In this section, we are concerned with the file system, rather than printer, aspects of redirection.

Microsoft first used the redirector interface since DOS 3.1 to allow DOS programs to transparently access all of the file systems. (But this coincided with the version of DOS to first support networking, so it's commonly assumed that the redirector interface is the vehicle DOS provided for the implementation of network services such as IBM PC LAN.)

Microsoft uses the redirector interface to provide CD-ROM access under DOS through the Microsoft CD-ROM Extensions (MSCDEX). Other users of the interface include network operating systems from Banyan and 3Com. Novell's NetWare 2.1x uses the redirector and, starting with version 4.0, so does Novell NetWare.

It is worth stressing the usefulness and power of the redirector interface. Although at times inconsistent and awkward in places as you will see, the possibilities for its application are enormous. However, Microsoft has not documented it and will not support it. In response to some customers' requests that redirector information be posted on its Online technical support service, Microsoft responded:

> The INT 2Fh interface to the network is an undocumented interface. Only INT 2Fh function 1100h and installed state of the network services is documented.
>
> Several third parties have reverse engineered and documented the interface of Windows for Workgroups' VNETSUP.386 (e.g., Addison Wesley), but Microsoft provides absolutely no support for programming to that API and we do not guarantee that the API will exist on future versions of MS-DOS.

The party line: it appears to be. Here's where you get the info, but you better not use it.

Rumor has it that the redirector is not exactly undocumented even Microsoft, except through oral history. Only in the bowels of Microsoft has much redirector source code and expertise been available to selected developers, thus making the network redirector a perfect example of how supposedly undocumented functionality is actually documented functionality. Such documentation, documentation even a lot worse than, is right: complete absence of documentation.

Novell's Undocumented Redirector Interfaces

So that we're not dumping unfairly on Microsoft, it's worth pointing out that its major competition, Novell, has its own undocumented redirector interface, two of them, in fact. NetWare 3.x and 4.x has an undocumented server interface for Name Spaces (Macintosh, HPFS, etc.). The name spaces are supposed to be dynamically allocated, but Novell hard codes the hook-in slots. Name Space NLMs (NetWare loadable modules, sort of a cross between DLLs and VxDs) then plug in to these pre-allocated slots.

Novell's NLM SDK describes a second redirector-like interface: "A new feature in NetWare v4.0 is the volume switch, which makes it possible for NetWare to access non-NetWare file systems, such as the NFS file system." While Novell mentioned this Volume Switch at one of its Brainshare conferences, it declined to release developer's documentation. According to one engineer, "they [Novell] like to handle this kind of thing strategically, which means they bring in the developer who is whining about it and give them documentation under strict NDA."

In a vain effort to maintain some technological consistency, the chapters in this book were originally forged. We've updated the material's experience with the redirector since the first edition of *Undocumented DOS*.

Because of the possibilities for confusion in terminology, we need to declare some terms. The term *redirector* or *redir* refers to all of the functionality and hooks DOS provides for foreign file systems and the *redirector program* refers to the program that uses the interface. More precisely, DOS at certain times calls INT 2Fh function 11xxh; this is called the redirector interface. Programs can receive these calls from DOS when they hook INT 2Fh. Such programs are called redirectors.

After the flowery, grandiloquent prose we've come to expect from Microsoft, the term *Installable File System* (IFS) signals a fundamental change in terminology. IBM introduced IFS as part of OS/2 1.2. IFS is a low-level interface for file systems to be developed and for use with multiple, simultaneous file systems. The first IFS file system under OS/2 IFS was the High Performance File System (HPFS). IFS was touted as a replacement for the old FAT file system. Another OS/2 IFS driver was the Novell NetWare Redirector.

In essence, IFS was to be a legitimized version under DOS 4 of the hidden, undocumented redirector interface under DOS. The fact that the initials IFS appeared frequently in DOS 4.0 documentation indicates that IBM's intent was to provide a stepping stone to help developers migrate toward OS/2 (particularly LAN Manager).

The IFS interface appears to have been implemented under DOS 4.0 using the IFSFUNC program, which made DOS act as a redirector. In other words, IFS was an extra layer on top of the redirector. Some additional subfunctions have appeared under the redirector interface to support what may be characterized as an overall abstraction of the existing redirector interface.

However, the reality is that IFS in the DOS world received no publicity at all, and DOS 4.0 was relegated to the dustbin of history. There is not much benefit to a further discussion of IFSFUNC, REDIRIFS, or any other DOS 4.0 specific specimen on the network redirector. We consider IFS here only insofar as it establishes and overlaps the redirector interface. In other words, we will refer to subfunctions of INT 21h that are redirector interface subfunctions even if they were first introduced in DOS 4.0 as IFS subfunctions.

In 1990, Microsoft will introduce an IFS Manager (IFSMGR.386) and IFSHELP.SYS. This, rather than the network redirector, will be the approved way for writing installable file systems. Apart from Microsoft, the benefits of IFSMGR over the redirector are: It will be documented, probably in the Chicago DDK. It will handle the case of multiple redirectors, and it will use segmentation rather than flat model DOS global variables in the SDA and so on.

In the remainder of this chapter, we delve further into what happens inside DOS for I/O calls using INT 2Fh AH=11h to see the circumstances under which DOS calls a redirector. A detailed specification for the INT 2Fh AH=11h interface is presented along with an extensive sample program, the Phantom Redirector. A second edition of *Undocumented DOS* should note that the rewritten PHANTOM incorporates far more extensive knowledge of the redirector interface than did the original PHANTOM.PAS. PHANTOM is too large a program to reproduce here in its entirety, but we present a detailed discussion of the assembly language file selector for I/O calls such as Open, Read, Chdir, and Mkdir. Complete source code is presented on the accompanying disk in \UNDOC2\CHAP8\PHANTOM.

Several readers of *Undocumented DOS* provided important additional information and clarifications on the redirector interface. Thanks to due to Carsten Bukholdt Andersen, Dave Andrews, Dwayne Bailey, Erick Engelke, Ian Lorien, Mike Kanos, David Markam, Karl Pate, Mitchell Schoenbrun, Mike Shiels, and Martin Westermeier.

For more information on the redirector interface, readers may wish to read the article, "A DOS Redirector for NetWare," by Jim Harper, *Dr. Dobb's Journal*, March 1993. Another interesting source of information on the redirector interface is the DOS emulation code (MDOS) in Carnegie Mellon University's Mach operating system; the relevant file is DOS_FS.C, available by ftp from cs.cmu.edu.

Using the Network Redirector Interface

In essence, we want to use the redirector interface to manufacture DOS drives. A DOS drive is any entity that has a drive letter in the DOS CDS and that behaves like a hard drive or floppy in that you can access it with normal DOS disk, directory, and file commands and INT 21h function calls. Whether there is magnetic media at the other end is irrelevant since a file system is a purely logical construct.

One can view almost any area as comprising a set of file operations. To take one example, say that every evening you log onto an information service, such as CompuServe, with a hierarchical structure of forums, message and library areas, sections, topics within message areas, and so on. Normally to access such services, you would dial up through the modem and send the service various command strings or menu selections. However, it might be more convenient to pretend that the information service is just another drive on your machine. Changing to drive J: and typing CD

IBM DOSSECURE.SYS for example might be equivalent to putting the IBMDOS.SYS code in ROM on IBM Concept PCs. It's quite simple. All you need is to designate a drive letter for the information server, install a piece of software that catches all disk directory and file requests sent to that drive, and have the software service these requests by issuing the proper CompuServe or BIX incantations. With a sufficiently fast modem, this would feel just like using a disk.

Front-End Hooks and Device Drivers vs. Back-End Redirectors There are several ways to catch INT 21h file I/O requests. One method does quite literally "catch" disk directory and file requests by hooking INT 21h and watching every function call that comes in. Novell NetWare earlier than 4.0 works this way; see NETX in Chapter 4. Because this method sees INT 21h calls before DOS itself, in fact DOS may not see some of them at all. It's sometimes called a *front end hook*. Novell uses it in *shell* because NETX puts a shell around the DOS APIs.

A front end hook is conceptually simple; see FUNCOB32C and DOSNETC in Chapter 2. But there are problems with hooking INT 21h and looking for all file and directory related calls for your specific drive. For one thing, you must keep separately with FCB- and handle-based calls. DOS file functions available to applications provide two very different interfaces. As you saw earlier in this chapter, the older FCB calls have the following implications:

- Inefficient concurrent open files because the state for the open file is kept in a user-supplied structure
- Wildcard file name specifications in Delete and Rename
- FCB functions cannot use pathnames

The file handle calls imply that:

- The concurrent open file count is limited to the FILES= line in CONFIG.SYS (that is, to the size of the SFT) and by any per-application limit to the size of its JFT
- Filenames can contain pathnames
- Uniqueness of file images cookie. Handle-based applications don't have to know the underlying JFT and SFT structures.

The redirector interface unifies the two access methods so that, with one exception discussed later, a redirector need not know by which method a file is being accessed. This allows the interface to function regardless of whether an INT 21h call is passed to DOS. This access method independence is great, but it doesn't eliminate the disadvantages of the redirector interface over INT 21h replacement. As the arguments favoring alternative file systems. Rather than having to duplicate the entire repertoire of file calls in the DOS program-level interface, including both FCB- and handle-based file access methods, a redirector can instead plug into a low-level interface much of the higher-level administrative work has already been accomplished, and does so with a homogenized, much narrower interface. For example, if the name strings used to open and otherwise manipulate files arrive at the redirector as they're entered, parts the DOS kernel has already done the work of resolving the drive and directory.

One major disadvantage with front-end INT 21h is that you must implement your own version of function 4Bh—EXEC. While Microsoft does provide a Set Execution State function (INT 21h AX=4B05h) for those who implement their own EXEC, there is little additional support. Each new version of DOS requires changes to one's EXEC code. In fact, it's reported that one reason for Novell's switch from hooking INT 21h to redirector hooks in INT 2Fh is that the company got burned on the DOS 5 changes to EXEC.

Another problem is that a front-end hook requires a fairly large amount of state just to correctly handle complex path names.

Unlock which you use the redirector support for undocumented calls such as Truename INT 21h AH=60h happens automatically. A front-end hook must explicitly code in support for all undocumented redirector interface. DOS takes care of cooking all file system requests for you.

On the other hand, the redirector interface is undocumented, so it may not seem to have any genuine advantage over hooking INT 21h. And of course, getting total support for DOS calls, both documented and undocumented, requires implementing the entire redirector interface. For example, support for INT 21h AX=452Bh Get Assigned List Entry, see NETDRV.C on Listing 8-15, requires that the redirector support INT 21h AX=1110h Do Redirection. In any case, the point remains that the redirector provides a more well-organized, narrower interface than does implementing an INT 21h front-end hook. We'll look at some problems with the INT 21h redirector interface a bit later on.

Another way to attach foreign file systems to DOS is, of course, to write an installable block device driver. But the device driver interface imposes certain restrictions on the file system. It must have a BPB, DPT, and FAT, which are not appropriate for all file systems. There is the added fact that device drivers are less portable to new machines (though DEVHLP.ASM from Chapter 9 helps a lot).

The alternatives to choosing INT 21h or writing a block device driver are to use the INT 21h functions or the redirector interface. It is often stated that "the network redirector grabs file system calls for the resource before INT 21h sees them" or words to that effect. While that is a good description of how the workstation shell in NETX works in NetWare 2 and 3, it is not a good description of the redirector, which operates at a level *below* or inside INT 21h. As we'll see, MS DOS's code for INT 21h takes care of calling INT 2Fh Function 11h when appropriate.

What DOS Provides On one side of the redirector interface are the redirector services. These consist of DOS data structures and a set of INT 21h calls issued at strategic times by the DOS kernel. What DOS can do most of for an operating system is clear out a tower-level program that responds to requests for services initiated by an application: the redirector interface specifies function calls that the operating system generates and that a redirector may execute and service. In normal DOS programming, you use INT 21h and DOS or else hook programs that hooked INT 21h services the call. In the redirector interface, DOS calls INT 2Fh AH=11h and uses the redirector service hooked. Function 11h defines several subfunctions, because DOS calls on several levels from inside INT 21h such a program must check and redirector accordingly. In contrast to the NETX style front-end hook.

The data structures created by the redirector interface include SysVars, the Current Directory Structure (CDS), the System File Table (SFT), and the Swappable Data Area (SDA).

The SysVars structure, obtained through undocumented INT 21h function 52h, provides the address of the CDS table and the LASTDRIVE value. A redirector is responsible for initializing many of these variables, restoring the CDS for use by those drive letters. For the most part, only calls with drive letters in the CDS are redirected via INT 2Fh AH=11h. In contrast, front-end hook programs typically pass all calls to the redirector. Novell NetWare 2 and 3, for example, can have drive letters start *after* LASTDRIVE. DOS primarily cares about three fields in the CDS: the current directory string, the offset of the root directory in that string, and the flags word.

As we saw in the earlier sections of this chapter, an SFT entry holds the state that DOS maintains for each open file. In system DOS appears to be interested only in the offset of the SFT: the open mode flags, which describe the access [read, write, and sometimes] of the file; the device information flags word, which tells whether the device is a block or character device, whether it has been written to, and some [other] flags; the date, time, and file size; and the current position fields. While the SFT is a DOS structure, it contains fields that are mostly for the use by the device driver. And while the SFT was designed for DOS to manage files on its FAT-based file system, and so contains fields that deal with units of sector and cluster, a redirector based on some other file system may use those fields in whatever way it needs.

The most important structure for the redirector interface is the Swappable Data Area. DOS is usually in a critical section that can be re-entered using the SDA. This is expanded in more detail in Chapter 9, which includes a section on building INRs with the SDA. The SDA is that area of the DOS data segment which must be saved and restored to provide for DOS reentrancy. Also data that, however, the SDA is also that part of the DOS data segment that contains the global data required by a network redirector. This data includes key DOS variables such as those recording critical error status, a pointer to the current Disk Transfer Area, the current wildcard mask for a file search attributes for Find First and Find Next, and so on.

Origins of the SDA

Tim Farley

[Some programmers wonder why a single tasking operating system like MS-DOS has a Swappable Data Area in the first place. The following brief historical note was written by Tim Farley, author of the forthcoming book *Undocumented NetWare*, to be published by Addison-Wesley in early 1994.]

I always find it helpful to understand the historical background behind APIs. The fact that the "server" portion of NetWare Lite uses the DOS SDA got me to thinking about why DOS includes an SDA in the first place.

That NetWare Lite is a redirector provides a clue. Perhaps the SDA was part of the other Microsoft Networks code introduced with DOS 3, and was originally designed to allow the implementation of a background network server program, which would obviously get into some situations where it would need to re-enter DOS to serve multiple tasks. MS-NET, and its derivatives like the IBM PC LAN Program were peer-to-peer networks very similar in concept to NetWare Lite.

To test this theory, that Microsoft introduced the SDA into DOS to support redirectors, and especially peer-to-peer "servers," I went to Atlanta's Computer Fairgrounds and, lo-and-behold, there was a copy of the IBM PC LAN Program 1.00, which I promptly bought for a grand total of $2.50. I believe this was one of the first, if not the first, implementation of Microsoft Networks (MS-NET) and therefore might even be the first redirector.

I couldn't get the product (dated March 1985) to run on my hardware, but I was able to shoot it through the Sourcer disassembler from V Communications, and, sure enough, the server portion of IBM PC LAN 1.00 uses the DOS SDA function call (INT 21h, AX=5D06h). This is RECEIVER.COM, similar to SERVER.EXE in NetWare Lite. After calling INT 21h, AH=5D06h to get a pointer to the SDA, the code does a REP MOVSB, so you can see why the function uses the CX register to return the size of the swap-in-DOS area.

As one would expect, the client portion (REDIR.EXE, the equivalent of CLIENT.EXE in NetWare Lite) implements a redirector and makes very extensive calls to twenty-seven different DOS internal (INT 2Fh, AH=12h) functions. Clearly, the INT 2Fh, AH=12h calls, like the SDA, were intended for redirectors.

REDIR.EXE, RECEIVER.COM, and NET.COM also all extensively use INT 2Ah, including critical sections 5 and 0Fh.

IBM PC LAN Program 1.00 dates from March 1985, so that's the "date to beat" to find an earlier user of the DOS SDA.

Whereas multitaskers generally just copy entire blocks of the SDA without caring as to their contents (see Chapter 9), network redirectors must use specific fields in the SDA. Unfortunately, the SDA structure changed greatly from DOS 3.0 to DOS 4.0, so programs that want to work in DOS 3.0 as well as in DOS 4.0, 5.0, and 6.0 must cope with two different SDA structures. The Appendix shows the DOS 3.0-style SDA under INT 21h AX=5D06h and the DOS 4.0-style SDA, which also applies to DOS 5.0 and 6.0, under INT 21h AX=5D06h. Note, however, that the AX=5D06h call is for DOS 4.0 *only*. Even in DOS 5.0 and 6.0, one must use the same INT 21h AX=5D06h call as in DOS 3.0, but the SDA has the same format as in DOS 4.0. Totally confused yet? Fortunately, in DOS 4.0, you can also use INT 21h AX=5D06h, so it is best for those writing redirectors to just forget about the AX=5D06h call. But I'll be showing the DOS version to determine whether a DOS 3.0 or a DOS 4.0-style SDA is in use, a programmer can also construct a WORD flag that DOS keeps at offset 4 in its data segment. For example, this is how MSCDEX determines which style DOS segment is in use:

```
CURR_DTA_PTR    dw  20Ah    , offset in DOS 3 DS of CURR_DTA
CURR_DRV_PTR    dw  2E4h    ; offset in DOS 3 DS of CURR_DRV
;     etc   other DOS variables

mov ah, 52h
int 21h
mov word ptr DOS_DS, es     ; get SysVars ptr, ignore BX; ES = DOS DS
mov ax, word ptr es:[4]     , DOS_DS[4] = style; 0 = DOS 3.0; 1 = DOS 4+
mov DOS_DS_VERS, ax
;
cmp DOS_DS_VERS, 1          , is this DOS 4+ style DOS DS?
jz DOS_4_DS
jmp short done              , What about values other than 0 or 1?
;
DOS_4_DS
mov CURR_DTA_PTR, 32Ch      , offset in DOS 4+ DS of CURR_DTA
mov CURR_DRV_PTR, 336h      , offset in DOS 4+ DS of CURR_DRV
done
```

Observe that MSCDEX is *not* using the SDA but instead contains two sets of offsets into the DOS data segment. MSCDEX uses DOS DS:[4] to determine which set of offsets to use. Probably one MSCDEX call to allow for two functions is used, and word offsets into the DOS data segment. In general, third-party redirectors should use offsets from the start of the SDA address that INT 21h AH=5D06h returns.

Of the many fields in the SDA, a redirector needs access to only a large handful:

ERR_LOCUS_ERR_CODE	Locus and extended error code of last error
ERR_ACTION_ERR_CLASS	Suggested action and class of last error
CURR_DTA	Current Disk Transfer Area (DTA)
FN1, FN2	Filename work areas
SRCH_BLK	Four DWORDs: Last, First, Last, Next search data block (SDB)
FOUND_FILE	Directory entry for found file
FN1_TO_CHAR	ASCIIZ style filename for device name comparison
FN2_TO_CHAR	ASCIIZ style filename for Rename wildcard destination
SRCH_ATTR	Directory search attributes
OPEN_ATTR	File open mode
DRIVE_CDSPTR	Pointer to CDS for drive accessed
XOPEN_ACT	Extended open (21/6C) action code
XOPEN_ATTR	Extended open attributes
XOPEN_MODE	Extended open mode
REN_SRCH_BLK	Rename source search data block (SDB)
REN_FILE	Rename source directory entry

The DOS kernel refers to many of these fields as it services INT 21h calls. In fact, these are not fields in a genuine structure, but variables in DOS's own data segment, to which redirectors are given (or at least take) privileged access via the SDA.

Listing 8-24, DOSSTRUC.SCR, is an INTRSPY script that describes only the fields in the DOS structures that are important to a redirector. Other script files used to investigate the interface will include this script. The script uses a feature of INTRSPY that we failed to mention in Chapter 5 (Undocumented INTRSPY): the ability to specify fields in a structure that INTRSPY skips over when asked to dump the entire structure.

Listing 8-24: DOSSTRUC.SCR

```
; DOSSTRUC.SCR
; Undocumented DOS structures relevant to the redirector interface
; This uses the undocumented INTRSPY "skip" feature.

;; Current Directory Structure entry - All DOS versions
structure CDS fields
    CURR_PATH (byte,asciiz,67)
    CDS_FLAGS (word,hex)
    f1 (byte,skip,10)
    ROOT_OFS (word,dec)
    ; In DOS 4.0 and above there are a further 7 bytes of IFS/SHARE fields

;; Directory entry for 'found' file - All DOS versions
structure DIRENTRY fields
    FNAME_11CHAR (byte,char,11)
    ATTR_BYTE (byte,hex)
    f0 (byte,skip,10)
    F_TIME (word,hex)
    F_DATE (word,hex)
    START_CLSTR (word,hex) ; A redirector can reuse this field
    F_SIZE (dword,dec)

;; Search Data Block - All DOS versions
structure SDB fields
    DRIVE_NUM (byte,dec)
    SRCH_MASK (byte,char,11)
    DIR_ENTRY (word,dec) ; A redirector can reuse this field
    DIR_SECTOR (word,dec) ; A redirector can reuse this field
    f0 (byte,skip,4)

;; Lock/Unlock region of file structure
structure LOCKREC fields
    REGION_START (dword,dec)
    REGION_LEN (dword,dec)
    f0 (byte,skip,13)
    FILENAME (byte,asciiz,80)

;; Swappable DOS Area - DOS 3.1 to 3.3
;; Used in the form SDA_SEG:SDA_OFS->SDA3
structure SDA3 fields
    f0 (byte,skip,3)
    ERR_LOCUS (byte,hex)
    ERR_CODE (word,hex)
    ERR_ACTION (byte,hex)
    ERR_CLASS (byte,hex)
    DEVDRVR_PTR (dword,ptr)
    CURR_DTA (dword,ptr)
    f1 (byte,skip,30)
    DD (byte,dec)
    MM (byte,dec)
    YY_1980 (word,dec)
    f2 (byte,skip,96)
    FN1 (byte,asciiz,128)
    FN2 (byte,asciiz,128)
```

```
    SRCH_BLK (SDB)
    FOUND_FILE (DIRENTRY)
    f3 (byte,skip,81)
    FN1_11CHAR (byte,char,11)
    f4 (byte,skip)
    FN2_11CHAR (byte,char,11)
    f5 (byte,skip,11)
    SRCH_ATTR (byte,hex)
    OPEN_MODE (byte,hex)
    f6 (byte,skip,48)
    DRIVE_CDSPTR (dword,ptr)
    f7 (byte,skip,72)
    REN_SRCFILE (SDB)
    REN_FILE (DIRENTRY)
;; Swappable DOS Area - DOS 4.0, 5.0, 6.0
;; Used in the form SDA_SEG:SDA_OFS->SDA4
structure SDA4 fields
    f0 (byte,skip,3)
    ERR_LOCUS (byte,hex)
    ERR_CODE (word,hex)
    ERR_ACTION (byte,hex)
    ERR_CLASS (byte,hex)
    DEVDRVR_PTR (dword,ptr)
    CURR_DTA (dword,ptr)
    f1 (byte,skip,32)
    DD (byte,dec)
    MM (byte,dec)
    YY_1980 (word,dec)
    f2 (byte,skip,106)
    FN1 (byte,asciiz,128)
    FN2 (byte,asciiz,128)
    SRCH_BLK (SDB)
    FOUND_FILE (DIRENTRY)
    f3 (byte,skip,88)
    FN1_11CHAR (byte,char,11)
    f4 (byte,skip)
    FN2_11CHAR (byte,char,11)
    f5 (byte,skip,11)
    SRCH_ATTR (byte,hex)
    OPEN_ATTR (byte,hex)
    f6 (byte,skip,51)
    DRIVE_CDSPTR (dword,ptr)
    f7 (byte,skip,87)
    SPOP_ACT (word,hex)
    SPOP_ATTR (word,hex)
    SPOP_MODE (word,hex)
    f8 (byte,skip,29)
    REN_SRCFILE (SDB)
    REN_FILE (DIRENTRY)
;; System File Table entry - All DOS versions
structure SFT fields
    C_HANDLES (word,dec
    OPEN_MODE (word,hex)
    ATTR_BYTE (byte,hex)
    DEV_INFO (word,hex)
    DEVDRV_PTR (dword,ptr)
    ST_CLSTR (word,dec) ; A redirector can reuse this field
    F_TIME  word,hex
    F_DATE (word,hex)
    F_SIZE (dword,dec)
    F_POS (dword,dec)
    LAST_REL_CLSTR  word,dec) ; A redirector can reuse this field
    LAST_ABS_CLSTR (word,dec) ; A redirector can reuse this field
    DIR_SCTR_NO (word,dec) ; A redirector can reuse this field
```

```
DIR_ENTRY_NO (byte,dec) , A redirector can reuse this field
FNAME_11CHAR (byte,char,11)
; other fields
```

Note the "A redirector can reuse this field" comment at some places in DOSNAME.RUC SCR When we discuss the Phantom source code, you will see that Phantom uses a slightly different version of the SFT than that shown earlier in this chapter The meaning of the fields that DOS maintains must of course remain unchanged Normally DOS expects that the redirector will fill in certain fields This expectation is a critical part of the redirector interface

What a Redirector Must Supply On the other side of the interface is the redirector itself be it MSCDEX the PCLAN program the hypothetical CompuServe redirector or this chapter's demonstration redirector the Phantom A redirector normally starts itself as a TSR program and installs into the chain of INT 2Fh handlers gets the vector to the current INT 2Fh handler stores it as the next handler in the chain and then sets the INT 2F vector to point to itself When INT 2Fh is invoked the redirector's INT 2Fh handler receives control If the INT 2Fh call is not for the redirector AH" 11h" it will pass control to the next handler in the chain In this way the redirector monitors all INT 2Fh calls and filters out all but redirector interface calls

One major problem with this interface is the use of INT 2F As you saw with the INTCHAIN program in Chapter 6 every TSR and its brother must be cooperative for this multiplex interrupt It is not uncommon to have ten or more handlers in the INT 2Fh chain see Figure 6 1 The performance problems with INT 2Fh may become possible reason for Microsoft's apparent move away from the redirector interface in the direction of a Novell NETX style client Look even while Novell itself is moving toward the redirector

Another problem with the redirector interface is that it provides no assistance when multiple redirectors are present Each redirector must decide on a subfunction by subfunction basis which INT 21h API calls it will chain to another previously loaded redirector When both MSCDEX and NetWare use the redirector interface the chaining necessary to make it work becomes a nightmare

Because INT 2Fh redirectors are called by DOS they have access to the swappable DOS and can call INT 21h redirectors when grabbing I O requests before DOS ever sees them For example INT 2F redirectors have little choice over the DOS file naming scheme more on this in Chapter 23 However whereas an INT 21h hook at least theoretically can access any file naming convention it wants

Tracing an Open, Revisited

Much earlier in this chapter we used INTRSPY to trace the code the COPY command was using on a local drive COMMAND COM called INT 21h AH 0Fh to fill in what is called a block device driver watch out this use of "block" is not the same as in Section 8 called INT 13h We now need to trace the same activity for a redirector drive This can be a network drive a CD ROM drive provided by MSCDEX or even an XMS RAM disk provided by the Phantom Sample programs developed later in this chapter

We can't use the exact same DISKSCR batch file we used to produce Figure 8 1 because DISKSCR includes SHSCR and network redirector drives don't have associated block device drivers However removing SHSCR results in an INTRSPY script that we can use to see what happens to a COPY command on a redirector drive

```
C:\UNDOC2>phantom /s256 h:
256Kb XMS allocated
Phantom installed as H

C:\UNDOC2>copy con h foo bar
this is foo.bar
^Z
        1 file(s) copied

C:\UNDOC2>intrspy

C:\UNDOC2>cmdspy compile disk command /c copy h foo bar h bar.foo
```

However the resulting INTRSPY report doesn't show anything occurring "inside" the INT 21h function 6Ch call

```
216C: Extended Open/Create: H:FOO.BAR
AX=6C00 BX=0040 CX=0000 DX=0101
216C: done, file is 0005
```

Well of course it doesn't show anything inside the INT 21h AH=6Ch call! Why should it? There is no block device driver installed for the drive, and it seems unlikely that an XMS RAM disk would call INT 13h, which is the BIOS disk function.

So what *does* happen inside an INT 21h on a network redirector drive? DOS issues INT 2Fh AH=11h calls to the network redirector. To see this, we can create a very simple INTRSPY script which tracks entry and exit into a few INT 21h calls and tracks any calls to INT 2Fh AH=11h. 2F11.SCR is shown in Listing 8-25.

Listing 8-25: 2F11.SCR

```
; 2F11.SCR
intercept 21h
    function 3Ch
        on_entry output "21/3C: Create   (ds:dx->byte,asciiz,64)
        on_exit  output "21/3C: Create done: " ax
    function 3Dh
        on_entry output "21/3D: Open " (ds:dx->byte,asciiz,64)
        on_exit  output "21/3D: Open done: " ax
    function 3Eh
        on_entry output "21/3E: Close " bx
        on_exit  output "21/3E: Close done " bx
    function 3Fh
        on_entry output "21/3F: Read " bx
        on_exit  output "21/3F: Read done " bx
    function 40h
        on_entry output "21/40: Write File " bx
        on_exit  output  21/40  Wrote done " bx
    function 6Ch
        on_entry output "21/6C: Ext Open/Create " (ds:si->byte,asciiz,64)
        on_exit  output "21/6C  Ext Open/Cr done: " ax

Intercept 2Fh
    function 11h
        on_entry output "   2F/" ax

run "command /c %1 %2 %3 %4 %5 %6 %7 %8 %9"
report
```

The results from this script are far more interesting:

```
C:\UNDOC2>cmdspy compile 2f11 copy h:foo bar h bar foo
21/6C: Ext Open/Create H:FOO.BAR
   2F/1123
   2F/112E
21/6C: Ext Open/Cr done: 0005
21/3F: Read 0005
   2F/1108
21/3F: Read done 0005
21/3E: Close 0005
   2F/1106
21/3E: Close done 0005

21/6C: Ext Open/Create H:BAR FOO
   2F/1123
   2F/112E
21/6C: Ext Open/Cr done: 0005
```

```
   2F/1123
21/40: Write File 0005
   2F/1109
21/40: Write done 0005
21/3E: Close 0005
   2F/1106
21/3E: Close done 0005
```

The indenting of INT 2Fh calls within INT 21h calls provides a clear picture of how the network redirector interface works. For example, calling INT 21h AH=3Fh, Read File, on a network redirector drive results in DOS sending an INT 2Fh AX=1108h to the redirector.

```
21/6C Open/Create -> 2F/1123 and 2F/112E
21/3F Read -> 2F/1108
21/40 Write -> 2F/1109
21/3E Close -> 2F/1106
```

In DOS 5.0 and higher, the COPY command happens to use INT 21h AH=6Ch. If a file had instead been opened with the older INT 21h AH=3Dh call, DOS would have issued an INT 2Fh AX=1116h rather than the AX=112Fh I've shown above. It's important to understand that DOS usually only makes these 2F=11 calls when the network bit is set in the current CDS's flags or in an SFT entry's device info word. For example, here's how MS DOS decides whether to issue the INT 2Fh AX=1108h Read call:

```
    ; ES:DI points to an SFT entry
    test    byte ptr es:[di+6], 80h , test network bit in SFT dev info
    jz      not_redir
    mov     ax, 1108h
    int     2fh

not_redir:
```

Likewise, here's how DOS decides whether to make the INT 2Fh AX=1103h Mkdir call:

```
    ; ES:DI points to the current CDS
    test    byte ptr es:[di+44h], 80h    , test network bit in CDS flags
    jz      not_redir
    mov     ax, 1103h
    int     2fh
not_redir:
```

Even if the bit is set in the CDS, has the network bit set, there are still a few redirector calls that DOS issues. Experimentation with INTRSPY and inspection of a DOS disassembly show that several redirector calls (such as Function Instructions 1Eh, 20h, 22h, 23h, and 25h) are essentially broadcasts that DOS issues, trying to discover whether a redirector is installed or not.

Furthermore, there are a few relatively obscure redirector calls (subfunctions 18h and 19h) that don't require a CDS at all. These are used, for example, by LAN Manager named pipes. But for the most part, when a redirector receives a call setting the network bit in a CDS entry, likewise a redirector must set the network bit in the SFT device info word for any files opened on its drives.

So far, it seems as if there are just a few redirector calls and that these correspond closely to the documented INT 21h calls. However, we haven't done much to the redirector drive yet—just copy a single file. We need to try DIR, MD, CD, RD, and so on, to get a general idea of which redirector calls DOS makes. We can simplify the INTRSPY script even further to print out nothing but the INT 2Fh AX function number:

```
intercept 2fh function 11h
    on_entry output ax
```

If we then run a few commands on the drive and sort the results, we can get some idea of the range of redirector calls that DOS issues.

```
C:\UNDOC2>cmdspy report | sort | uniq

1101            ; remove dir
1103            ; make dir
1105            ; change dir
1106            ; close file
1108            ; read file
1109            ; write file
110C            ; get disk space
1113            ; delete file
1116            ; open file
1117            ; create/truncate file
111B            ; find first
111C            ; find next
111D            ; close all for PSP
1120            ; flush all buffers
1122            ; proc term hook
1123            ; qualify pathname
1125            ; redirected printer mode
112E            ; extended open file
```

Although this program provides a record of random activity on the drive, even more, there are other, less common but still important redirector calls that DOS issues. For example, calling INT 21h AX=5F02h with the INT2FDRV.C program in Listing 8-15 results in a call to INT 2Fh AX=1111h. Basically, to write a good working, portable redirector requires implementing the whole bloody interface. You can only guess at what for example, some of the calls listed above.

Tapping the calls with INTRSPY is a fairly random way to determine what parts of the redirector interface are used. To see a full redirector calls DOS makes, it is better to examine the actual DOS source code to see ways to support. Using the INT2121.INT file generated with NUTDIS in Chapter 6, we can see exactly which INT 21h AH=11h calls DOS makes and when. For example:

```
                        INT21_00:               ; Reset Drive

;
; do INT 2Ah AX=8001h, call func to flush all buffers (calls code for
; INT 2Fh AX=1215h in loop), do INT 2Ah AX=8101h
;
FDC8:4DBC   B8FFFF          MOV AX,FFFF
FDC8:4DBF   50              PUSH AX
FDC8:4DC0   B82011          MOV AX,1120         ; flush all disk buffers
FDC8:4DC3   CD2F            INT 2F              ; 2F/1120
FDC8:4DC5   58              POP AX
FDC8:4DC6   C3              RET
```

Inspection of the DOS 5.0 source indicates that it calls redirector subfunctions 0, 1, 3, 5, 0Ah, 0Ch, 0Fh, 11h, 13h, 1Bh, 1Eh, 1Fh, 1Ah, 20h, and 21h. There's a commercial redirector should implement these calls which are described in a moment.

So far we have seen which redirector calls DOS makes but haven't seen any details of how they work. To see the interface in more detail, we can follow a File Open call a little more closely using another INTRSPY script, REDIR.SCR. Listing 8-26:

Listing 8-26: REDIR.SCR

```
;; REDIR.SCR -- for DOS >= 4.00
Include "dosstruc"      ; see listing 8-24

Intercept 21h
    function 6Ch
        on_entry
            output      DOS OPEN (6Ch) ========== ======== ======"
            output "File name: " (ds:si->byte,asciiz,40)
            output "Open mode: " (bl,hex) "h"
```

```
        on_exit
            output
            output "== 6Ch OPEN Completed "
            if (cflag == 1) sameline "(FAILED " (ax,dec) ") ==========="
            if (cflag == 0) sameline "(Handle " (ax,dec) ") ==========="
intercept 2fh
    function 11h
        subfunction 2Eh
            on_entry
                output
                output "-- 2F Open (2Eh) -----------------"
                output  File name  " (sda_seg:sda_ofs->SDA4.FN1)
                output "Open mode: " (sda_seg:sda_ofs->SDA4 $POP_MODE)
                output "Uninitialized SFT:"
                output (es:di->$FT)
            on_exit
                output
                output "   2F Open (2Eh) completed "
                if (cflag == 0)
                    sameline "-----------------"
                    output "Completed SFT:"
                    output (es:di->SFT)
                if (cflag == 1) sameline "(FAILED " (ax,dec) ") ----------"
run "command /c type %1"
report
```

This script takes as a parameter the name of a file that exists on the redirected drive. For variety, we'll look at a file on an MSCDEX CD-ROM drive I rather than on Phantom drive H

```
C:\UNDOC2>cmdspy compile redir i:read me > redir.log
```

This types out the file entered as the parameter. If the file is on a redirected drive, as in the MSCDEX-based example I: READ.ME, the file REDIR.LOG contains something like this

```
== DOS OPEN (6Ch) ====================
File name: i:read me
Open mode: 00h
-- 2F Open (2Eh) -----------------
File name: \\L.A.\READ.ME
Open mode: 0000
Uninitialized SFT
SFT.C_HANDLES                   : 65535
SFT.OPEN_MODE                   : 0000
SFT.ATTR_BYTE                   : 20
SFT.DEV_INFO                    : 0042
SFT.DEVDRV_PTR                  : 0116:13A4
SFT.ST_CLSTR                    : 7002
SFT.F_TIME                      : 2800
SFT.F_DATE                      : 1689
SFT.F_SIZE                      : 47845
SFT.F_POS                       : 47845
SFT.LAST_RELCLSTR               : 5
SFT.LAST_ABSCLSTR               : 867
SFT.DIR_SCTR_NO                 : 0
SFT.DIR_ENTRY_NO                  11
SFT.FNAME_11CHAR                : COMMAND.COM
-- 2F Open (2Eh) completed -----------------
Completed SFT
SFT.C_HANDLES                   : 65535
SFT.OPEN_MODE                   : 0002
SFT.ATTR_BYTE                   : 01
SFT.DEV_INFO                    : 8048
```

```
SFT.DEVDRV_PTR                  : 0057 0DF3
SFT.ST_CLSTR                    : 9933
SFT.F_TIME                      : 2395
SFT.F_DATE                      : 7ADC
SFT.F_SIZE                      : 21[redacted]
SFT.F_POS                       : 0
SFT.LAST_RE.CLSTR               : 21560
SFT.LAST_ABSCLSTR               : 0
SFT.DIR_SCTR_NO                 : 56026
SFT.DIR_ENTRY_NO                : 2
SFT.FNAME 11CHAR                : README  ME
== 6Ch OPEN Completed (Handle 5) ==========
```

This shows the 21Dh Open function called with the raw filename string in DS:SI as specified to the redirector. Also the resultant redirector Open call substitution 16h called with the SDA FN1 field pointing to a fully qualified filename: C:\README.ME. Note that the filename for files on network redirected drives contains a leading with a double backslash. It also shows an annotated SFT passed to the redirector Open function with data left over from previous use: COMMAND.COM in this case, and the SFT initialized by MSCDEX. This gives you an idea of the sort of detail DOS takes care of before calling a redirector as well as the tasks for which the redirector is responsible.

The Phantom

To explain the interface in detail, it is best to use a real example. Here then, is the Phantom. The Phantom program creates a phantom drive, that is, the drive is not based on a physical disk drive, but rather uses XMS as its media. Radically changed from its guise in the first edition of *Undocumented DOS*, the Phantom is now a fully functioning and useful extended memory RAMDisk TSR.

- It supports all DOS file system commands that you can run on a network drive, with the exception of CHKDSK, FORMAT, SYS and DBLSPACE. These all operate on native DOS devices, such as those in INT 25h, 26h and generic IOCTL, which do not get redirected through the redirector interface.
- It behaves like a very fast hard disk and is transparent to all DOS and Windows applications. Note, however, that loading SHARE has no effect. Phantom does not signal sharing violations.
- It works under DOS 3.1 thru 6.0, exclusive. It has also been tested under a prerelease version of DOS 7.0 (Chicago).
- It supports LFN as well as handle based file operations.
- Under the test version of Phantom, the number of directories and files on the drive is limited only by the amount of XMS memory allocated for the drive on the command line. As this book was printed, we found that Phantom currently supports only two subdirectory levels.
- As an installable TSR redirector it has some advantages over conventional device driver RAM disks like RAMDRIVE.SYS in that you can load it when you need it, unload it when you don't need it, and pick a disk size & XMS allocation on the fly to suit the application.
- It illustrates not only, but also undocumented knowledge of the redirector interface, but principles of a FAT based file system as well.

Its usage is:

```
PHANTOM [-Snnnn] d: [-U]
-Snnnn  specifies size of RAM disk in KB of XMS
d:      specifies drive letter to use
-U      unloads latest copy of Phantom loaded
```

The /S switch is particularly important because by default the Phantom takes all XMS memory, this is not necessarily what you want.

You can run multiple copies of Phantom specifying a different drive letter each time. Note that it unloads the most recent invocation.

Here's a brief sample session with the Phantom device where the entire contents of the Interrupt List from the UNDOC2\INTRLIST is XCOPYed to a new \INTRLIST subdirectory on Phantom drive H:

```
C:\UNDOC2\CHAP8>phantom h:
396Kb XMS allocated
Phantom installed as H:

C:\UNDOC2\CHAP8>md h:\intrlist

C:\UNDOC2\CHAP8>xcopy C:\UNDOC2\INTRLIST\*.* h:\intrlist
Reading source file(s)...
C:\UNDOC2\INTRLIST\COMBINE.BAT
C:\UNDOC2\INTRLIST\FILE_ID.DIZ
C:\UNDOC2\INTRLIST\GLOSSARY.LST
C:\UNDOC2\INTRLIST\INTERRUP.1ST
C:\UNDOC2\INTRLIST\INTERRUP.A
Reading source file(s)
C:\UNDOC2\INTRLIST\INTERRUP.B
;    . okay, we get the idea .
C:\UNDOC2\INTRLIST\_ADVERT.TXT
       30 File(s) copied

C:\UNDOC2\CHAP8>dir h:\intrlist

 Volume in drive H is PHANTOM
 Directory of H:\INTRLIST

COMBINE  BAT       150 05-06-93  11:06a
FILE_ID  DIZ       200 05-24-93  12:34a
GLOSSARY LST     23998 03-21-93   4:42p
INTERRUP 1ST     60877 05-24-93  12:34a
INTERRUP A      290154 05-24-93  12:34a
INTERRUP B      242488 05-24-93  12:34a
; ... lots of big files
_ADVERT  TXT      1845 01-28-92  10:19p
       30 file(s)    3096942 bytes
                      941056 bytes free
```

Naturally, processing the three-megabyte Interrupt List on this Phantom drive, whether with a tool such as grep or with Hacker's Quick Software's INTERVUE, is very fast.

All the classic text-based DOS file system calls are here. We have created an entity which looks like a drive, behaves like a drive, and yet which runs entirely outside of our INT 21h function 11h handler and XMS. As this book was going to press, a beta site discovered that Phantom crashes if you have HIMEM.SYS, but don't have DOS=HIGH. This, right now, Phantom inadvertently requires DOS=HIGH.

Phantom Implementation

With the C source code for Phantom, we can resume our trace into the DOS Open call and see how a redirector like Phantom handles this and other INT 21h calls that DOS sends it. The source code for Phantom is so large, 2400 lines of code, to print here in its entirety, but it's on the accompanying disk as \UNDOC2\CHAP8\PHANTOM.C. Here, we look at selected portions of PHANTOM.C to see how a redirector handles DOS Open, Read, Find First, Change Directory, and Make Directory.

Initializing the CDS First, however, we must see how the Phantom sets itself up to be called in the first place. As we saw earlier, DOS issues most of the INT 21h AH=11h redirector calls only if

the network bit is set in the current CDS or in the device info word of the current SFT. Before we can see how the Phantom handles INT 2Fh calls, then, we must see how it sets up the CDS. This, appropriately enough, is done in PHANTOM.C's set_up_cds() function shown in Listing 8-27.

Listing 8-27: PHANTOM.C set_up_cds()

```
// V3_CDS_PTR and V4_CDS_PTR are CDS structures for DOS 3, DOS 4+
// LOLREC_PTR is pointer to LOLREC (LOL = List of Lists = SysVars)

// global variables
LOLREC_PTR  lolptr,              /* pointer to List Of Lists */
uchar       our_drive_no,        /* A: is 0, **not** 1 !! */
uint        cds_root_size,       /* Size of our CDS root string */
char far *  cds_path_root = "Phantom:\\", /* Root string for CDS */

extern void fatalprog(char * msg);   /* print message, exit to DOS */

void set_up_cds(void)
    {
    V3_CDS_PTR our_cds_ptr = lolptr->cds_ptr;

    if (our_drive_no >= lolptr->last_drive)
        fatalprog("Drive letter higher than last drive");

    if (_osmajor == 3)
        our_cds_ptr += our_drive_no;
    else
        {
        V4_CDS_PTR t = (V4_CDS_PTR) our_cds_ptr;
        t += our_drive_no;
        our_cds_ptr = (V3_CDS_PTR) t;
        }

    // Check that this drive letter is currently invalid (not in use)
    // Test both Physical (0x4000) and Network (0x8000) at same time.
    if ((our_cds_ptr->flags & 0xc000) != 0)
        fatalprog("Drive already assigned...");

    // Establish our 'root'
    cds_root_size = _fstrlen(cds_path_root);
    _fstrcpy(our_cds_ptr->current_path, cds_path_root);
    our_cds_ptr->current_path[_fstrlen(our_cds_ptr->current_path) - 3] =
        (char) ('A' + our_drive_no);
    _fstrcpy(cds_path_root, our_cds_ptr->current_path);
    our_cds_ptr->root_ofs = _fstrlen(our_cds_ptr->current_path) - 1;
    current_path = our_cds_ptr->current_path + our_cds_ptr->root_ofs;

    // Set both Physical (0x4000) and Network (0x8000) at same time.
    // David Maxey says that a non-network redir such as Phantom
    // should set 0xC080, not 0xC000.  0x80 is the REDIR_NOT_NET bit
    // used by MSCDEX.  If 0x80 is not set, Phantom shows up in
    // NET USE on DEC Pathworks and IBM LAN Server.  This point
    // comes from an Interrupt List entry supplied by Geoff Chappell.
    our_cds_ptr->flags |= 0xc000;
    }
```

On entry to set_up_cds(), the global variable our_drive_no holds the zero-based (A=0, not 1) drive code we've specified for the new Phantom drive, and set_up_cds() uses this to get a far pointer to the CDS entry for that drive. The function ensures that the drive doesn't exceed LASTDRIVE (in other words, it's the CDS we've got) and ensures that the drive is not already in use by testing both the Physical and Network bits in our_cds_ptr->flags.

Assuming that the specified drive letter can be Phantomized, the function sets the current path in the CDS entry to a default string such as "Phantom:\" and sets the root_ofs field to the backslash, so that the root directory is "\". For this drive, the TRUENAME command would print the string "Phantom:\" directly from the CDS.

Most DOSPARAM.SET sets up cds.0 turns on the CDS entry's Network and Physical bits (cds.0.wFlags |= 0xC000), thereby declaring that disk, directory, and file requests for this drive will be recognized and handled by a redirector. If you remove a Phantom drive with PHANTOM U, the program switches off these bits (cds.0.wFlags &= 0x3FFF). See the comment in set up cds, which notes that this should really be 0x4080, not 0xC000. As you can tell, this was a last-minute change.

The Redirector INT 2Fh Handler Once the appropriate bits have been set, there must of course be an INT 2Fh handler to act as the redirector. The Phantom installs an INT 2Fh handler called redirector(), in the normal way:

```
prev_int2f_vector = _dos_getvect(0x2f);      // 21/35
_dos_setvect(0x2f, redirector);              // 21/25
_dos_keep(0, tsr_paras);                     // 21/31: TSR
```

The Phantom's INT 2Fh handler is shown in Listing 8-28.

Listing 8-28. PHANTOM.C redirector()

```
// ALL_REGS are compiler-specific register parms to interrupt functions
#define     MAX_FXN_NO          0x2E
#define     STACK_SIZE          1024
#define     FCARRY              0x0001

// global variables
int         curr_fxn,           /* Record of function in progress */
ALL_REGS    r,                  /* Global save area for all caller's regs */
uint        dos_ss,             /* DOS's saved SS at entry */
uint        dos_sp,             /* DOS's saved SP at entry */
char        our_stack[STACK_SIZE],  /* our internal stack */
uint far*   stack_param_ptr,    /* ptr to word at top of stack on entry */
int         filename_is_char_device, /* generate_fcbname found CHAR dev)  */

void succeed_void()  { r.flags &= ~FCARRY; r.ax = 0; }

// dispatch table, fxnmap, and is_call_for_us() are discussed below

void interrupt far redirector(ALL_REGS entry_regs)
    {
    static uint save_bp;

    _asm sti;
    // Make sure that AH = 11h and that AL <= MAX_FXN_NO
    // i.e., only support INT 2Fh AX=1100h through AX=112Dh
    if (((entry_regs.ax >> 8) != (uchar) 0x11)  ||
        ((uchar) entry_regs.ax > MAX_FXN_NO))
            goto chain_on;

    curr_fxn = fxnmap[(uchar) entry_regs.ax];   // AL=subfunction

    if ((curr_fxn == _unsupported) ||
        (! is_call_for_us(entry_regs.es, entry_regs.di))) // Listing 8-29
        goto chain_on;

    // Set up our copy of the registers
    r = entry_regs;

    // Save ss:sp and switch to our internal stack. We also save bp
    // so that we can get at any parameter at the top of the stack
    // (such as the file attribute passed to subfxn 17h)
    _asm mov dos_ss, ss;
    _asm mov save_bp, bp;
    stack_param_ptr = (uint far*) MK_FP(dos_ss, save_bp + sizeof(ALL_REGS));

    _asm {
        mov dos_sp, sp
        mov ax, ds
```

```
        cli
        mov ss, ax          // New stack segment is in Data segment.
        mov sp, offset our_stack + STACK_SIZE -2
        sti
        }

    succeed(); // Expect success!

    // DO IT! Call the appropriate handling function
    // unless we already know we need to fail (NUL, CON, AUX, etc.)
    // fn.ename_is_char_device is set inside is_call_for_us()
    if (filename_is_char_device)    fail(5);
    else                            dispatch_table[curr_fxn]();

    // Switch the stack back
    _asm {
        cli;
        mov ss, dos_ss;
        mov sp, dos_sp;
        sti;
        }

    // put the possibly changed registers back on the stack, and return
    entry_regs = r;
    return;

    // If the call wasn't for us, we chain on.
chain_on:
    _chain_intr(prev_int2f_vector);
    }
```

The redirector function sees all INT 2Fh calls whether they are redirector related or not, and whether they are intended for one of the Phantom's drives or not. For every call

- if it is a redirector call, that is AH=11h, and
- if it is a call for one of its drive letters (see below), and
- if it is a supported call,

then redirector() dispatches the appropriate procedure to carry out the requested subfunction. If any of these parameters is false, the redirector passes control to the previous handler in the (possibly very long) INT 2Fh chain.

Phantom also ensures that you don't try to create files on the Phantom drive with names such as NUL or CON that belong to installed character device drivers. This is call for use function calls generate fcbfunc(), which in turn calls is_character_device(), which is a C wrapper around INT 2Fh AX=1223h; generate_fcbfunc() then sets the global variable filename_is_char_device. Incidentally, despite fcbfunc() the directory and other references to FCBs in the Phantom code has nothing to do with FCBs. This very confusing name merely refers to 11 character file names, such as one finds in FCBs but also in many other parts of DOS.)

Having established that it has a supported redirector call for one of its drives, redirector() prepares a copy of the registers as they were on entry and then switches SS:SP to an internal stack, which is simply a static array of bytes in the DGROUP. Upon entry to redirector(), SS is the DOS stack segment but DS becomes our DS courtesy of the C interrupt keyword. Switching to our own stack satisfies Turbo C's assumption. Furthermore, the DOS stacks are not very large (about 300 bytes, see Chapter 6), and having our own stack ensures that we do not run out of stack space.

Now, consider what is the only reason that use of this internal stack might raise. By using an internal stack and always positioning it at the top of it on entry, our redirector is not reentrant—the contents of the stack are always destroyed by each successive call. However, our redirector is called only by DOS, and as we saw in Chapter 6, DOS does exactly the same thing upon entry to Int 21h for all the functions which generate calls to us. To all intents and purposes, DOS itself is not reentrant, so our lack of

redirector is installed as well. However, the reader may wish to ponder how this interacts with software that uses the Swappable Data Area to reenter DOS.

Having switched stacks, redirector dispatches the appropriate handler function for the requested subfunction. When the subfunction returns, redirector switches SS:SP to the original values upon entry, restores the registers, and returns.

How Do We Know the Call Is for Us? DOS allows the installation of multiple redirectors. If redirector receives a INT 2Fh AH=11h call but one which is not intended for one of its drives, the function passes the call on in the normal way with the chain interrupt function (provided with both Microsoft C and recent versions of Borland C++).

How does redirector decide that it should handle a call rather than pass it on to MSCDEX, NetWare, LANtastic, or some other redirector? Since there may be a chain of redirectors, each wanting to service only those calls that relate to the drives that it is redirecting, there must be a way of determining whether a particular redirector call (this one making the comments) is for you.

The redirector function passes the ES and DI registers to its call, for us to figure out, well, whether the call is for us. This function is shown in Listing 8-29.

Listing 8-29 PHANTOM.C is call for us()

```
// _close_file, _unlock_file, _lock_file, etc. are 2F/11 AL subfunction numbers

// SFTREC_PTR  far ptr to an System File Table (SFT) entry
// SRCHREC_PTR  far ptr to a findFirst Search Data Block (SDB)
// V3_SDA_PTR, V4_SDA_PTR  far ptrs to the Swappable Data Area (SDA)

int is_call_for_us(uint es,uint di)
    {
    filename_is_char_device = 0;

    // The first "if" checks for the bottom 6 bits of the
    // device information word in the SFT.  Values > LASTDRIVE
    // relate to files not associated with drives, such as LAN Manager
    // named pipes (thanks to David Markun)
    if ((curr_fxn >= _close_file && curr_fxn <= _unlock_file)
        || (curr_fxn == _seek_from_end)
        || (curr_fxn == _unknown_fxn_20) )     // file related
        {
        SFTREC_PTR sft_ptr = (SFTREC_PTR) MK_FP(es,di), // check SFT
        // Markun says 0x3F mask is WRONG! See subfunction 1Ch below
        return (sft_ptr->dev_info_word & 0x3F) == our_drive_no;
        }
    else if (curr_fxn == _inquiry)        // 2F/11/00  succeed automatically
        return TRUE;
    else if (curr_fxn == _fnext)          // find Next
        {
        SRCHREC_PTR psrchrec;             // check search record in SDA
        if (_osmajor==3)
            psrchrec=&((V3_SDA_PTR) sda_ptr)->srchrec;
        else
            psrchrec=&(((V4_SDA_PTR) sda_ptr)->srchrec);
        // Markun says 0x3F mask is WRONG! See subfunction 1Ch below
        return (uchar) (psrchrec->drive_no & 0x3F) == our_drive_no;
        }
    else                                  // everything else
        {
        uchar far * p;
        if ( _osmajor==3)
            p= (V3_SDA_PTR) sda_ptr)->cdsptr;   // check CDS
        else
            p=((V4_SDA_PTR) sda_ptr)->cdsptr;
        if ( fmemcmp(cds_path_root, p, cds_root_size)    0)
            {
```

```
        // If a path is present, does it refer to a character device?
        if (curr_fkn != _dskspc)
            generate ioctlname(ds),    // eventually call 2F/1223
        return TRUE;
        }
    else
        return FALSE;
    }
}
```

The redirector's call for us() uses depends on the type of operation to be performed. If the 2F/1123 call is to open a file (such as Read, Write, Commit, or Close), DOS sets up ES:DI to point to the SFT entry for the file before issuing the INT 2Fh call. See the redirector specification later in this chapter. The location of the word in the SFT entry that contains the file's drive number in the lower 6 bits is a simple masking and comparison operation for us() to call for use to ascertain that the call is one of ours:

```
((SFTREC_PTR) MK_FP(es,di))->dev_info_word & 0x3F)    our_drive_no
```

If the call is for a function such as Find Next, the SRCH_BLK structure in the SDA contains a drive number (actually a 1-based number) at the beginning of the structure, and again we need only mask and compare the bottom 6 bits of that drive to see if the findnext is for us:

```
((sdb *) (psp:>srchrec))->drive_no & 0x3F)    our_drive_no
```

Actually, this 0x3F mask should probably be changed to 0x1F. In addition, bit 6 (0x40) should be tested. See section 16 later in this chapter for the gory details. Another last minute correction by David Markum!

Each redirector in the DOS world has already received a DRIVE_PARMS_RECORD for the CDS at boot time. Your redirector can access this record during the redirector call. The most reliable way to compare the CDS entries is to match the backslash characters in their CURRENT_PATH fields up to the root offset. (Phantom drives are an exception. Do strcmp() on "PHANTOM" which appears when a program opens a file from drive B: MSCDEX (the equivalent is a string such as "D:\".)

This example assumes that is_for_us() always returns TRUE for a drive on which the redirector must check

Another Detection Method: The Network UserVal

Tim Farley

The methods used in is_call_for_us() may not be practical for all redirectors, such as those that own a whole list of drives in the CDS.

Also comparing the string in the CDS is not practical on some network redirectors, because it might contain one of several server or volume names, and even if you recognized them, that might not conclusively identify the drive as yours. (For instance, suppose you had two different LANs loaded, and you had servers on both LANs that had the same name.)

A different method requires callers to set the UserVal parameter in CX when calling the INT 21h AH=5F03h Make Network Connection function (this shows up at the redirector as an INT 2Fh AX=1123h, with 5F03h on the stack). This UserVal is stored at offset 4Dh in the CDS and is a magic value that identifies your drives. For example:

```
if (cds[drive].Flags & NETWORK)
    if (cds[drive].u_NET_parameter == my_magic_number)
        return CALL_IS_FOR_ME;
```

NetWare 4.0 appears to use this, as it requires callers to put 'NW' (574Eh) in CX when calling INT 21h AX=5F03h. Of course, your redirector could store the magic value at offset 4Dh itself if appropriate and not rely on the caller. Comparing this one word is far easier than comparing an entire string.

Handling a Read The redirector function has finally decided that a call is intended for one of its drives. Let's say the call is a Read—in other words, that a program has called INT 21h AH=3Fh (File Read) or INT 21h AH=21h (FCB Random Read), and that DOS has bailed out to call INT 2F AX=1108h, which has wound up on redirector's doorstep. How does Phantom handle the subfunction 8 Read call?

Looking back at redirector() in Listing 8-28, you can see that given a supported redirector subfunction number in AL, the subfunction is called through a dispatch table:

```
if (fxnmap[AL] != _unsupported)
    dispatch_table[AL]();
```

As you would expect, dispatch_table is nothing more than an array of function pointers:

```
PROC dispatch_table[]= {
    inquiry,          /* 0x00h */
    rd,               /* 0x01h */
    unsupported,      /* 0x02h */
    wd,               /* 0x03h */
    unsupported,      /* 0x04h */
    cd,               /* 0x05h */
    closfil,          /* 0x06h */
    commfil,          /* 0x07h */
    readfil,          /* 0x08h */
    writfil,          /* 0x09h */
    //
    } ;
```

Having made short work of the preamble, the punch line is that when DOS calls INT 2Fh AX=1108h, the Phantom redirector winds up calling the readfil() function shown in Listing 8-30. This is where we can start to see in the detail for the INTRSPY trace we produced earlier:

```
21/3F: Read 0005
   2F/1108
      redirector() (Listing 8-28)
         is_call_for_us() (Listing 8-29)
         readfil() (Listing 8-30; see alternate in Listing 8-38)
21/3F  Read done 0005
```

Listing 8-30: PHANTOM.C readfil() (INT 2Fh AX=1108h)

```
/* DOS System File Table entry - all DOS versions  NOTE!!! This is
   slightly different from the standard DOS SFT structure.  Some
   of the fields are for the redirector's use to treat as
   it sees fit.  Others, of course, are maintained and used by
   DOS, so the r- meaning must never be changed.  */
typedef struct {
    uint        handle_count, open_mode,
    uchar       file_attr,
    uint        dev_info_word;
    uchar far * dev_drvr_ptr,
    uint        start_sector, file_time, file_date,
    ulong       file_size, f*_pos,
    uint        rel_sector, abs_sector, dir_sector, dir_entry_no,
    char        file_name[11];
    ulong       share_prev_sft,
    uint        share_net_machine_num, owner_psp,
```

```
    // other fields
    } SFTREC, far* SFTREC_PTR;

void fat (uint err) { r.flags |= FCARRY; r.ax = err; }

void read_data(long far *file_pos_ptr, uint *len_ptr, uchar far *buf,
    uint start_sector, uint far* last_rel_ptr, uint far* last_abs_ptr);

// Read from File - subfunction 08h
void readfil(void)
    {
    SFTREC_PTR p = (SFTREC_PTR) MK_FP(r.es, r.di);
    if (p->open_mode & 1) { fat(5); return; }  // access denied

    if ((p->file_pos + r.cx) > p->file_size)
        r.cx = (uint) (p->file_size - p->file_pos);
    if (! r.cx) return;     // nothing to do
    // fills caller's buffer and updates the SFT for the file
    read_data(&p->file_pos, &r.cx, ((V3_SDA_PTR) sda_ptr)->current_dta,
        p->start_sector, &p->rel_sector, &p->abs_sector);
    }
```

Gosh, that was easy. That's all reading does involve. When presented this way, it looks like you could write a DOS clone, the world's most valuable piece of code, one weekend while your spouse is out of town.

Now, if you're writing a DOS for a system a bit harder than this. For example, later on, I'll be using 8 x 8 cm floppy disks, so I'll need a version of readfil with critical error handling. As a RAM disk that handles XMS rather than a real floppy disk, Phantom can be a bit cavalier about errors.

You can see that readfil takes the caller's ES:DI and treats it as an SFTREC_PTR. This matches what is said about the Read subfunction in the redirector specification later in this chapter.

```
Subfunction 08h
Read from File
Inputs          ES:DI -> SFT for file to read from
                CX = count of bytes to read
                SDA CURR_DTA -> user buffer to read data into
Outputs         Carry set + error code in AX if error encountered
                if no error, CX = bytes actually read
                SFT updated
```

In fact, the Phantom readfil function is little more than a C version of this specification, taking parameters from the SFT and updating the SFT. The Read function reads at the current file position stored in the SFT, so the only other parameters needed are the number of bytes to read (CX) and the address of the caller's buffer (DTA). All the updating of the SFT is done in the lower-level read_data function, which, however, knows nothing about SFTs. The function readfil passes read_data the addresses of all the SFT fields that need updating.

Back in DOS 3.0 (Listing 8-19), we dumped out some SFT fields. However, a key value not shown in DOS 3.0's dump is the current file position. This is maintained not only in the SFT file position field but also in the current and absolute sector fields. Phantom treats part of the SFT in its own way, as noted earlier, a redirector can interpret the meaning of some fields in the SFT. These fields are used and updated by readfil and, of course, also by writfil (not shown).

These fields are also updated when a program calls INT 21h AH=42h, Move File Pointer (a/k/a lseek). Interestingly, however, in DOS 4.0 and higher, these lseek calls usually don't appear at the redirector's doorstep. Instead, DOS fiddles with the SFT directly without bothering the redirector. There's one exception, having to do with seeking from the end of a file, in which DOS will call the redirector. See the disassembly of lseek in Chapter 6, Listing 6-20.

The Phantom XMS File System At this point we have satisfied the redirector specification. The internals of the read data function don't matter for the purposes of understanding the redirector. For example, read data could produce random data such as stock market prices on demand.

However, let's keep going and see how Phantom organizes the file system. Because Phantom implements a FAT-based file system, it is worth examining. It only to reinforce the points made much earlier in this chapter about the FAT and DOS directory structures. The read data function is shown in Listing 8-31.

The file system implemented in Phantom uses XMS extended memory. The way that it organizes the storage of directory and file information and data is similar, but not identical to the DOS FAT-based file system. Of course, there's no requirement that a redirector use a FAT file system; that in fact is a primary reason to use the redirector at the first place. Since it treats XMS memory as though it were simply a hard disk formatted into sectors, it would be relatively easy to modify Phantom to work on any random-access medium. There are separate interesting issues involved with sequential access media such as tape.

The Phantom file system is sectored just into 1024-byte chunks of XMS instead of 512-byte chunks of disk. Phantom divides its disk space XMS allocation into two areas:

- The FAT and directory copy. Since a FAT entry that is a WORD in size allows for approximately 64K clusters, a 1024-byte cluster allows the FAT to manage a full 64MB of XMS memory. Therefore, Phantom removes the distinction between sectors and clusters and deals exclusively in sectors.
- The data storage area, which accommodates not only the file and subdirectory data, but the root directory as well, which Phantom treats as simply another subdirectory, except that DOS provides special treatment for the root directory, assigning it a fixed contiguous size not accessible through the FAT.

Apart from this, Phantom emulates the DOS file system fairly closely. It uses the same directory entry structure and the same FAT-management techniques as DOS. It is worth stressing again, though, that none of this similarity is required of a redirector.

Listing 8-31: PHANTOM.C read_data()

```
#define     SECTOR_SIZE     1024    /* 1024b/sector allows for 64M of XMS */

uchar       sector_buffer[SECTOR_SIZE], /* general purpose sector buffer */
uint        last_sector = 0xffff; /* last sector read into sector buffer */

/* Uses FAT to find next sector in chain for current file/directory */
extern uint next_FAT_sector(uint abs_sector);

void read_data(long far *file_pos_ptr, uint *len_ptr, uchar far * buf,
        uint start_sector, uint far* last_rel_ptr, uint far* last_abs_ptr)
    {
    uint start, rel_sector, abs_sector;
    uint  , count,  en = *len_ptr,

    start = (uint  (*file_pos_ptr / SECTOR_SIZE);
    if (start < *last_rel_ptr)
        {
        rel_sector = 0;
        if ((abs_sector = start_sector) == 0xFFFF)  // end of FAT chain
            {
            *len_ptr = 0;
            return;
            }
        }
    else
        {
```

```
        rel_sector = *last_rel_ptr,
        abs_sector = *last_abs_ptr,
        }

    while (len)
        {
        start = (uint) (*file_pos_ptr / SECTOR_SIZE);
        if (start > rel_sector)
            {
            if ((abs_sector = next_FAT_sector(abs_sector)) == 0xFFFF)
                {
                *len_ptr -= len; goto update_sectors;
                }
            rel_sector++;
            continue;
            }
        i = (int) (*file_pos_ptr % SECTOR_SIZE);
        count = min((uint) SECTOR_SIZE - i, len);
        if (count < SECTOR_SIZE)
            {
            if (! get_sector(abs_sector, &sector_buffer))
                {
                *len_ptr -= len; goto update_sectors;
                }
            last_sector = abs_sector;
            fmemcpy(buf, (uchar far *) &sector_buffer[i], count);
            }
        else if (! get_sector(abs_sector, buf))
            {
            *len_ptr -= len; goto update_sectors;
            }
        len -= count;
        *file_pos_ptr += count;
        buf += count;
        }
update_sectors:
    *last_rel_ptr = rel_sector;
    *last_abs_ptr = abs_sector;
    }
```

The read data function contains a standard loop over the number of bytes of data the caller requested. In this FAT-like system, there is effectively one sector per cluster—each 1024 bytes. If the number of bytes requested exceeds one sector, read_data has to use the FAT to find the location of the next sector to read. The function calls next_FAT_sector to get PHANTOM.SYS on disk, which uses abs_sector as an index into the FAT. Of course, not FAT sectors may have to be read in a FAT sector from the VMS disk. This operation involves first writing the current FAT sector back out to disk.

As happens with a real disk, Phantom reads entire sectors at a time. If the remaining bytes the caller requests are fewer than a full sector, read_data can read directly into the user's buffer, so it uses sector_buffer (which is then copied via fmemcpy) into the user's buffer.

Since Phantom operates on the network, it does not implement a buffer pool, but most redirectors should. Write data from redirector drives is not by default integrated into the DOS buffers pool, a redirector could call internal DOS functions such as INT 2F: AX=1210h (Find Unreferenced Disk Buffer) or INT 2F: AX=1201h (Make Buffer Most Recently Used). Note also that data from redirector drives is not cached by programs such as SmartDrive, which work off INT 13h. This is especially important for slow media such as CD-ROM. MSCDEX incorporates its own sector buffers (the location and number of which you can set with MSCDEX /m:), but there is now a market for third-party CD-ROM "accelerators" (i.e., caches). As noted earlier, SmartDrive 4.2 and higher, included with MS-DOS 6.2, can cache data from CD-ROM drives.

In Listing 8-31, you can see that read data gets the actual data by calling get_sector(). This is a macro in PHANTOM.C:

```
#define get_sector(sec, buf) \
    xms_copy_to_real(xms_handle, (ulong) SECTOR_SIZE * (sec), \
        SECTOR_SIZE, (uchar far *) (buf))
```

The xms_copy_to_real() function is in turn just a C wrapper around XMS function 0Bh (Move Extended Memory Block). This current trace of a DOS read for a Phantom drive now looks like this:

```
21/3F: Read 0005
   2F/1108
      redirector() (Listing 8-28)
         is_call_for_us() (Listing 8-29)
         read() (Listing 8-30, see alternate in Listing 8-38)
            read_data() (Listing 8-31)
               XMS function 0Bh
21/3F: Read done 0005
```

In other words, a normal DOS read turns into a call to XMS function 0Bh—exactly as one would hope from an XMS RAM disk!

Handling an Open Having seen how Phantom handles a DOS read, we'll now step back to consider how it got opened in the first place. Rather than the Extended Open/Create call, we'll look at the simpler Open File call (INT 21h AH=3Dh), which DOS turns into a redirector Open (INT 2Fh AX=1116h). The redirector's handler for this subfunction, opnfil(), is dispatched via Listing 8-28 in the same way as was the read() function shown in Listing 8-32.

In Listing 8-32, fcbname_ptr and srch_attr_ptr are among several Phantom global far pointer variables set up to reference DOS data structures, such as the SDA and other parts of DOS. This sounds disgusting, but the redirector interface depends on the redirector having direct access to DOS's own global data. Another tip: note that names such as fcbname_ptr have nothing to do with FCBs and merely refer to 11-character filenames.

Listing 8-32: PHANTOM.C opnfil() (INT 2Fh AX=1116h)

```
/* these are version-independent pointers to various frequently used
   locations within the various DOS structures */
// note  fcbname_ptr has nothing to do with FCBs! just 11-char filename
char far *  fcbname_ptr;        /* ptr to 1st FCB-style name in SDA */
uchar far * srch_attr_ptr;      /* ptr to search attribute in SDA */

extern int contains_wildcards(char far* path);
// ffirst(), fill_sft(), init_sft(): see below

void opnfil(void)
    {
    // DOS calls the redirector with ES:DI pointing
    // to an uninitialized SFT entry.
    SFTREC_PTR p = (SFTREC_PTR) MK_FP(r.es, r.di);

    if (contains_wildcards(fcbname_ptr)) { fail(3); return; }

    // opening a file requires first finding the file
    *srch_attr_ptr = 0x27; // Archive+System+Hidden+Readonly+Normal
    ffirst();
    if (!r_ax)
        {
        //    and then using the ffirst search record to fill in the SFT
        fill_sft(p, TRUE, FALSE);
        init_sft(p);
        }
    }
```

Like readdir, opendir() retrieves all. It does little more than call ffirst() (Find First) and then fill sfirst() and sfnext() (Find Next) in essence. Open = get a name and set DTA from DOS + Find First + set SFT.

The ffirst() function is screwy. Testing 8.33 this is the same function that would be called if a program did an INT 21h AH=4Eh Find First on a redirector drive. Before calling ffirst(), opendir() sets the search attribute in the SDA (srch_attr_ptr) to 0x27, indicating (for those readers who do not carry the entire DOS programmer's reference around in their heads) that system, hidden and read-only files should be found in addition to normal files. This matches DOS behavior on local drives, where you can DIR a directory that has the hidden bit set and DIR finds it.

Listing 8-33: PHANTOM.C ffirst() (INT 2Fh AX=111Bh) and fnext() (AX=111Ch)

```
char far *  filename_ptr,       /* ptr to 1st filename area in SDA */
SRCHREC PTR srchrec_ptr,        /* ptr to 1st Search Data Block in SDA */

/* Finds the sector number of the start of the directory entries for
   the supplied path */
extern int get_dir_start_sector(char far* path, uint far* abs_sector_ptr);

void ffirst(void)                       /* FindFirst - subfunction 1Bh */
    {
    char far* path;
    int success;

     * Special case for volume-label-only search  must be in root */
    if (path = (*srch_attr_ptr == 0x08) ?
            filename_ptr : _fstrrchr(filename_ptr, '\\'))
        *path++ = 0;

    if (path) *path = '\\';
    success = get_dir_start_sector(filename_ptr, &srchrec_ptr->dir_sector);
    if (! success) { fail(3); return; }

     fmemcpy(&srchrec_ptr->srch_mask, fcbname_ptr, 11);

    srchrec_ptr->dir_entry_no = -1;
    srchrec_ptr->attr_mask = *srch_attr_ptr;
    srchrec_ptr->drive_no = (urhar) (our_drive_no | 0x80);

    /* ffirst()'s embedded call to fnext() admittedly looks a little
       odd.  This arises from the view that findfirst is simply a
       findnext with some initialization overhead.  findfirst has to
       locate the directory in which findnext is to iterate, and
       initialize the SDB state to 'point to' the first entry.  It
       then gets that first entry, using findnext.  ffirst() does
       initialization, and fnext() is the "workhorse." */
    fnext();

    /* To mimic DOS behavior, a findfirst that finds no matching entry
       returns an error 2 (file not found), whereas a subsequent findnext
       that finds no matching entry should return error 18 (no more
       files).  Having just done the embedded fnext(), we need to turn any
       error return value into what is appropriate for ffirst() */
    if (r_ax == 18) r_ax = 2;
    }

DIRREC PTR  dirrec_ptr,         /* ptr to 1st found dir entry area in SDA */

/* Get next directory entry that matches specified mask, continuing
   from the supplied starting position (from the previous find) */
extern int find_next_entry(char far* mask, uchar attr_mask,
    char far* filename, uchar far * attr_ptr, ulong far* file_time_ptr,
    uint far* start_sec_ptr, long far* file_size_ptr,
    uint far* dir_sector_ptr, int far* dir_entryno_ptr);

void fnext(void)                        /* FindNext  - subfunction 1Ch */
    {
    if (! find_next_entry(srchrec_ptr->srch_mask,
            srchrec_ptr->attr_mask, dirrec_ptr->file_name,
```

```
            &dirrec_ptr->file_attr, &dirrec_ptr->file_time,
            &dirrec_ptr->start_sector, &dirrec_ptr->file_size,
            &srchrec_ptr->dir_sector, &srchrec_ptr->dir_entry_no))
        far=1;
    }
```

Aside from some special handling for volume labels, find_first calls get_dir_start_sector (not shown, see P_FAN_DOM.C) on disk to locate the requested file. If the file is located, find_first fills in the first Search Data Block in the SDA.

We're looking at find_first because, as you saw in Listing 8-32, the open() function in Phantom internally calls find_first to locate files. Having called find_first to locate the requested file to open, open() proceeds to "do the actual open" which involves nothing more than setting the correct fields in the system-wide SFT entry that DOS passes at ES:DI. Phantom's open() calls fill_sft and init_sft to initialize the SFT, using the SDB structure pointed to by find_first and the directory entry structure pointed to by find_next (see the comments in Listing 8-33 to see why find_first calls find_next). The fill_sft and init_sft functions are shown in Listing 8-34.

Listing 8-34: PHANTOM.C fill_sft() and init_sft()

```
#define     FREE_SECTOR_CHAIN(sec)  \
    while  (sec) != 0xFFFF) (sec) = set_next_sector((sec), 0)

extern ulong dos_ftime(void);   // call 2F/1200

void fill_sft(SFTREC_PTR p, int use_found_1, int truncate)
    {
    _fmemcpy(p->file_name, fcbname_ptr, 11);
    if (use_found_1)
        {
        p->file_attr = dirrec_ptr->file_attr,
        if (truncate)
            {
            FREE_SECTOR_CHAIN(dirrec_ptr->start_sector);
            p->start_sector = 0xffff;
            p->file_time = dos_ftime(), // includes date, calls 2F/1200
            p->file_size = 0L;
            }
        else
            {
            p->start_sector = dirrec_ptr->start_sector,
            p->file_time = dirrec_ptr->file_time,
            p->file_size = dirrec_ptr->file_size,
            }
        p->dir_sector = srchrec_ptr->dir_sector,
        p->dir_entry_no = (uchar) srchrec_ptr->dir_entry_no,
        }
    else
        {
        p->file_attr   (uchar) *stack_param_ptr,  /* Attr is top of stack */
        p->file_time = dos_ftime();
        p->start_sector = 0xffff;
        p->file_size = 0;
        p->dir_sector = srchrec_ptr->dir_sector;
        p->dir_entry_no = 0xff;
        }
    }

extern void set_sft_owner(SFTREC_PTR sft),  // call 2F/120C

void init_sft(SFTREC_PTR p)
    {
    /* Initialize the supplied SFT entry. Note the modifications to the open
       mode word in the SFT.  If bit 15 is set when we receive it, it is an
       FCB open, and requires the Set SFT Owner internal DOS function to be
```

```
    cases  We don't understand this, but this is what MSCDEX does. */
if (p->open_mode & 0x8000)
    p->open_mode |= 0x00F0;     // File is being opened via FCB
else
    p->open_mode &= 0x000F;

// Mark file as being on network drive, unwritten to
p->dev_info_word = (uint) (0x8040 | (uint) our_drive_no);
p->file_pos    0,
p->rel_sector   0xffff,
p->abs_sector   0xffff,
p->dev_drvr_ptr   MK_FP(

if(p->open_mode & 0x8000)   // File is being opened via FCB
    set_sft_owner(p),       // Call 2F/1220
}
```

The `set_sft` and `init_sft` functions set fields in the SFT from a variety of sources:

- As usual, some SFT fields are set from the first byte of directory entry in the SDA `dirrec_ptr` and the current Sector Data Block in the SDA `sechdr_ptr`, which are themselves set by `first` and `next`.
- The SFT file size and date are converted into DOS time format by using DOS internal function INT 21h AX=1200h (`dos_timer`).
- The SFT device info word is set based on our drive no and the magic number 0x8040, which indicates a network file, but that it has not been written to, but is
- The SFT open mode is held over from an undocumented way for FCBs, but 15 in the open mode indicates an FCB Open.
- For an FCB Open, `set_sft` calls `set_sft_owner`, which is a C wrapper around INT 2Fh AX=1220h. Among other things, this DOS internal function uses the current PSP to set the SFT owner field.

For each file, or handle, the three SFT field types: those fields such as the above that the redirector sets; those that DOS uses; those fields that DOS leaves alone for the redirector's own internal use (see DOSSWAP.ASM, `SWAP_R_SFT`, step 8.24) and all those fields that DOS sets.

When Phantom's `getfsh` returns the results it is filled in SFT entries. As you saw in Listing 8-30, most of the fields `getfsh` copies to `opnfil` such as `p_stclu` `psc` and `p_start_sector` are subsequently used or readdle. Of course, most SFT fields are also changed by other DOS functions such as `Write` and `Lseek`.

Handling Chdir Having looked at how the Phantom handles the I/O set, we briefly examine Directory Management. How is the CD or `chdir` directory command implemented.

When a program issues an INT 21h AH=3Bh Change Directory or a redirector drive, a drive whose CDS has the network bit set, DOS generates an INT 2Fh AX=1105h. In the Phantom, this is handled in `net_IO` function shown in all its glory in Listing 8-35.

Listing 8-35: PHANTOM.C cd() (INT 2Fh AX=1105h)

```
char far *  filename_ptr,       /* ptr to 1st filename area in SDA */
char far *  current_path,       /* ptr to current path in CDS */

void cd(void)                   /* Change Directory - subfunction 05h */
    {
    /* Special case for root */
    if ((*filename_ptr != '\\') || (*(filename_ptr + 1)))
        {
        /* can't make directory with * or ? in name */
        if (contains_wildcards(fcbname_ptr)) { fail(3); return; }

        *srch_attr_ptr = 0x10;  // look for directory
        ffirst();   // calls fnext(), which sets dirrec_ptr
```

```
    if (r.ax || !(dirrec_ptr->file_attr & 0x10)) { fail(3); return; }
    }
  fstrcpy(current_path, filename_ptr);
}
```

We know CHDir.ADD.a.dir does anything but call first to verify that the specified directory string is valid and to copy the string into the current CDS. This makes sense. If you were to use a debugger to manually edit the CDS in memory, it would change your current directory, so conversely the DOS Change Directory function does little more than edit the CDS.

Handling Mkdir But how do directories come into existence in the first place, so that the call to ffirst in Listing 8-35 can find them? DOS directories are, of course, created with the MD command. Make Directory. This command calls INT 21h AH=39h, Mkdir, which in turn, for a redirected drive, calls INT 2Fh AX=1103h. You saw this in an earlier code fragment from a disassembly of DOS. In the Phantom, this is handled by the mkdir function shown in Listing 8-36.

Listing 8-36 PHANTOM.C mkdir() (INT 2Fh AX=1103h)

```
#define put_sector(sec, buf)      \
    xms_copy_fm_real(xms_handle, (ulong) SECTOR_SIZE * (sec), \
        SECTOR_SIZE, (uchar far *) (buf))
void mkdir(void)                    /* Make Directory - subfunction 03h */
    {
    /* special case for root */
    if ((*filename_ptr=='\\') && (!*(filename_ptr+1))) { fail(5); return; }

    if (contains_wildcards(fcbname_ptr)) { fail(3); return; }

    *srch_attr_ptr = 0x3f;                  // 0x3F = everything
    ffirst();                               // if ffirst() succeeds,
    if (r.ax == 0) { fail(5); return; }     //    directory already exists!
    if (r.ax != 2) return;                  // we WANT error 2 ( not found )
    // if any component part of path is wrong, we'll return error 3

    /* Although we initialize a directory sector, we actually don't need to,
       since we do not create . or .. entries. This is because
       a redirector never receives requests for . or .., in Chdir - DOS
       resolves the absolute path before we get it. If you want to
       see dots in DIR listings, create directory entries for them after
       put_sectors. But then you must take account of them in Rmdir. */
    last_sector = 0xffff;
    memset(sector_buffer, 0, SECTOR_SIZE);
    if (!find_free_ptr->start_sector.next_free_sector()) { fail(5); return; }
    set_next_sector(dirrec_ptr->start_sector, 0xffff);
    last_sector = dirrec_ptr->start_sector;
    if (!put_sector(dirrec_ptr->start_sector, &sector_buffer))
        { fail(5); return; }    // access denied

    /* finally, create entry for this directory. srchrec_ptr and
       dirrec_ptr were set in fnext, called from ffirst */
    if (!create_dir_entry(&srchrec_ptr->dir_sector, NULL, fcbname_ptr, 0x10,
        dirrec_ptr->start_sector, 0, dos_ftime())) // Listing 8-37
        { fail(5); return; }    // access denied
    succeed();
    }
```

When a MD is given on one of its drives, Phantom first has to run your new directory string through a series of tests:

- Has it been asked to create a root directory? (error 5 = access denied)
- Does the string contain wildcards? (3 = path not found)
- Does the path already exist? (access denied)

At first it may look strange that mdir calls first and, if first succeeds (ax == 0), mdir *fails*. But if you're creating a new directory, it cannot already exist, so for mdir to succeed, the first call must fail. Normally one looks for something in hopes of finding it. Here, mdir looks for the directory in the hopes of *not* finding it. The mdir function can only proceed if first returns error 2 (file not found).

On the other hand, if there are multiple path components, all the higher-level component parts must exist. For example, for an MD FOO\BAR\BAZ to succeed, both FOO and FOO\BAR must already exist. If you don't, mdir fails with error code 3 returned from first. The mdir function can only proceed if first returns error 2 (file not found).

At this point, mdir can go ahead and make the directory, which basically involves some sector manipulation. If this were DOS rather than the Phantom, it would, of course, manipulate clusters rather than sectors. As you'll see, mdir's steps involve getting a free sector, setting its FAT entry (next sector pointer) to 0FFFh, writing the sector to disk, and finally creating the entry for the new directory in its parent directory.

It won't be totally obvious from mdir how the new entry is plugged into the parent directory; that is, how MD FOO\BAR would end up smacking an entry for BAR into FOO's directory. The very end of the function, `is_create_dir_entry`, creates this directory entry, but it isn't clear how mdir locates the parent directory in which to plug it. As usual in the Phantom, the answer lies in the first function you see. You mdir calls first to ensure that the target directory doesn't already exist, but this is the only reason first is used. first also implicitly locates the new directory's parent.

Once `is_create_dir_entry` has located the new directory's parent directory, mdir creates the new directory entry by calling `create_dir_entry`. As shown in Listing 8-37, this function walks through a directory looking for a free (or deleted) entry. If a free entry can't be found in the current directory sector, `create_dir_entry` uses the FAT to find the next directory sector. If there isn't a next directory sector, `create_dir_entry` calls `next_free_sector` to create one. This new directory sector, assuming it can be allocated, is to be linked in the FAT to the current one. This FAT link is made by `set_next_sector`, also shown in Listing 8-37.

Listing 8-37 PHANTOM.C create_dir_entry() and set_next_sector()

```
int create_dir_entry(uint far *dir_sector_ptr,
    uchar far * dir_entryno_ptr, char far* filename, uchar file_attr,
    uint start_sector,  ong file_size, ulong file_time)
    {
    uint next_sector, dir_sector = *dir_sector_ptr,
    DIRREC* dr = (DIRREC*) &sector_buffer,
    int i;

    for (;;)
        {
        if (dir_sector != last_sector)
        {
            if (! get_sector(dir_sector, sector_buffer))
                return FALSE,
            else
                last_sector = dir_sector,
        }
        for (i = 0, i < DIRREC_PER_SECTOR; i++)
            {
            if (dr[i] file_name[0] && (dr[i] file_name[0] != (char) 0xE5))
                continue,   // looking for unused or deleted entry
            _fmemcpy(dr[i] file_name, filename, 11),
            dr[i] fi e_attr = fi e_attr,
            dr[i] fi e_time = file_time,     /  includes date
            dr[i] file_size   file_size;
            dr[i].start_sector = start_sector,
            *dir_sector_ptr   dir_sector;
```

```
            if (dir_entryno_ptr) *dir_entryno_ptr = (uchar) i;
            return put_sector(dir_sector, &sector_buffer);
            }

        // no free dir entry: get next, or allocate new
        if ((next_sector = next_FAT_sector(dir_sector)) == 0xFFFF)
            {
            if (! (next_sector = next_free_sector()))
                return FALSE;
            set_next_sector(dir_sector, next_sector);
            set_next_sector(next_sector, 0xFFFF);
            }
        dir_sector = next_sector;
        }
    }

uint        FAT_page[FATPAGE_SIZE]; /* buffer for FAT entries */
int         cur_FAT_page = -1,      /* index of FAT page in buffer */
int         FAT_page_dirty = FALSE; /* Has current FAT page been updated */
uint        free_sectors,           /* unallocated sectors on XMS disk */

/* Checks that the page of FAT entries for the supplied sector is in
   the buffer.  If it isn't, go get it, but write back the currently
   buffered page first if it has been updated. */
extern int check_FAT_page(uint abs_sector);

/* Update the FAT entry for this sector to reflect the next sector
   in the chain for the current file/directory */
uint set_next_sector(uint abs_sector, uint next_sector)
    {
    uint save_sector;

    if (! check_FAT_page(abs_sector)) return 0;

    save_sector = FAT_page[abs_sector - (cur_FAT_page * FATPAGE_SIZE)];
    FAT_page[abs_sector - (cur_FAT_page * FATPAGE_SIZE)] = next_sector;
    if (save_sector != next_sector)
        {
        FAT_page_dirty = TRUE;
        if (! save_sector)      free_sectors--;
        else if (! next_sector) free_sectors++;
        }
    return save_sector;
    }
```

Assuming create_dir_entry() has found or created a free directory entry, it initializes the directory using the function's parameters for name, file attributes, and start sector and writes it back to the directory sector in which it was found using put_sector(), a macro that calls xms_copy() in real.asm. As with xms_copy() in real.asm, this is a C wrapper around XMS function 0Bh, Move Extended Memory Block. In the Phantom XMS RAM disk, "writing" a sector involves a copy from conventional real mode memory to XMS, whereas "reading" a sector involves a copy from XMS to conventional memory.

While the creation of a directory entry in Listing 8-37 is unexceptional, it still helps to examine the code. Earlier in this chapter, we used directory entries without giving much thought to how fields such as file's starting sector come to be there in the first place. In create_dir_entry() and many other parts of Phantom, we can see the same structures from the operating system's view point, as well as how they are built as part of the operating system.

Here's my next trace through the Phantom code. Again, complete source code is available on disk as \CN1900\20\HAPS\PHANTOM.C.

Differences Between DOS Versions

Phantom works with DOS versions from 3.10, when Microsoft introduced the redirector interface, through to DOS 6.0. The interface has changed little in that time, except in one or two important

areas. Perhaps the most predictable change is that some subfunctions have been added to cater to new functions added to the INT 21h interface.

In DOS 4.0, for example, the Extended Open/Create function was introduced to make all types of file opens a single-step operation. At that time, a corresponding new redirector interface subfunction number, 23h, was added to handle Extended Open. The SDA also changed with DOS 4.0, and as seen in Listing 8.24, SPOP_ACTION, SPOP_MODE, and SPOP_ALIAS fields were added to support the special open functionality.

Another subfunction number introduced with DOS 4.0 was 21h. Some of the DOS internal commands use the undocumented DOS function 57h, which appears to trigger 21h at the redirector interface. However, both DOS function 57h and the redirector subfunction 21h are among those DOS 4.0 calls that disappear in later DOS versions, so we won't worry about them further. The following redirector specification quite deliberately writes off anything specific to DOS 4.0 as a dead end.

The Network Redirector Specification

The following table presents the known redirector subfunctions with usage parameters, and notes. Remember that DOS merely defines this specification and that any given redirector must supply the actual functions that meet this specification.

```
Subfunction 00h
Installation Check
Inputs:         None
Outputs:        AL = 00h not installed, OK to install
                AL = 01h not installed, not OK to install
                AL = FFh installed, OK to install
```

1. A redirector should call this subfunction at initialization and should not load if the subfunction returns 01h in AL. But returns 00h or FFh, it's OK to load. These two values allow a redirector to opt not to load if another redirector is already present. Once installed, the redirector should respond to other redirectors that call this subfunction, returning with FFh in AL unless there is reason to disallow subsequent redirectors to load, in which case the redirector should set AL to 01h.
2. A redirector should always handle this call. This convention means that it is up to the most recently loaded redirector to decide whether any further redirectors may be loaded. You can see this working in the INTCHAIN program from Chapter 6: run INTCHAIN 21 -c 100, and notice that the most recently loaded redirector takes the call. Again, the whole issue of chaining redirectors is complicated.
3. MSCDEX looks for previous instances of itself by pushing 0DADAh on the stack before calling INT 2Fh/AX=1100h. After return from the INT 2Fh, it tests if the top of the stack is still 0DADAh. But not if the INT 21h handler have changed 0DADAh to something else, or concludes that MSCDEX is already loaded. It returns instead of going TSR. Meanwhile, the MSCDEX handler for subfunction 0 sets the word at the top of the stack to 0ADADh. Note what David Maxey calls the "stack" in this interface: the resident code sets 0ADADh, but the prospective resident code tests only for 0DADAh. At least one program that impersonates MSCDEX (Novell's CD Networker 4.x and 5.x) looks for DADAh on the stack and changes it to ADADh if there was a genuine MSCDEX that loaded before CD Networker. Networker does not change DADAh to ADADh, but instead moves it somewhere else, allowing a caller to detect that something special is going on.

```
Subfunction 01h
Remove Directory
Inputs:         SDA.FN1 = fully qualified directory name
Outputs         Carry set, error code in AX if error encountered
```

1 The redirector should either compare the supplied CDS PTR pointer in the SDA with the address of the CDS for one of its drives or, preferably, the referenced CDS contents with the contents of its own CDS to determine if the call is intended for its drive

2 The redirector should ensure that it doesn't remove the *current* directory by comparing SDA FN1 with the current path in the CDS; attempts to remove the current directory should be failed with error code 16

```
Subfunction 03h
Make Directory
Inputs          SDA.FN1 = fully qualified directory name
Outputs         Carry set, error code in AX if error encountered
```

See note 1 for subfunction 01h

```
Subfunction 05h
Change Current Directory
Inputs:         SDA.FN1 = fully qualified directory name
Outputs         Carry set, error code in AX if error encountered
```

1 See note 1 for subfunction 01h

2 The redirector must update the CURRR PATH field of the CDS for the drive

```
Subfunction 06h
Close File
Inputs          ES:DI -> SFT for file to close
Outputs         Carry set, error code in AX if error encountered
                SFT completed if no error
```

1 The redirector should use the bottom 6 bits of the DEV_INFO field of the SFT pointed to by ES:DI to determine whether the call refers to a file on one of its drives (numbers 0 = A: to 25 = Z:) and so forth. There may be an issue involving the DPB field within the SFT

2 The redirector should decrement CURHANDLES first field in the SFT and create or update the record information for the file that was opened for writing, but 0 or less. Failing to decrement the SFT handle count creates orphaned files. The redirector can decrement the handle count directly via sft_handle_count or by calling INT 2Fh AX=1208h

```
Subfunction 07h
Commit File
Inputs          ES:DI -> SFT for file to commit (flush buffers)
Outputs         Carry set, error code in AX if error encountered
```

See note 1 for subfunction 6

```
Subfunction 08h
Read from File
Inputs:         ES:DI -> SFT for file to read from
                CX = count of bytes to read
                SDA CURR_DTA -> user buffer to read data into
Outputs:        Carry set, error code in AX if error encountered
                if no error, CX = bytes actually read
                CX = 0 to indicate end of file
                SFT updated
```

1 See note 1 for subfunction 6

2 The redirector should also update the F_POS field in the SFT

3 Don't forget to set CX = 0 to indicate EOF

```
Subfunction 09h
Write to File
```

```
Inputs:         ES:DI -> SFT for file to write to
                CX = count of bytes to write
                SDA CURR_DTA -> user buffer from which to write data
Outputs:        Carry set, error code in AX if error encountered
                if no error, CX = bytes actually written
                SFT updated
```

1 See note 1 for subfunction 0

2 The redirector should also update the F_POS and F_SIZE fields in the SFT

3 This call should fail with access denied if the file was opened for reading only (bits 0 and 1 both zero)

4 If CX is 0, truncate the file to the current file position

```
Subfunction 0Ah
Lock/Unlock Region of File
Inputs:         ES:DI -> SFT for file
                CX:DX = region offset (DOS 3.0.X)
                SI = high word of region size (DOS 3.X)
                Word at top of stack = low word of region size (DOS 3.X)
                BL = 0 (Lock) or 1 (Unlock) (DOS 4+)
                DS:DX -> LOCKREC for region to lock (DOS 4.0+)
Outputs         Carry set, error code in AX if error encountered
```

1 See note 1 for subfunction 0

2 The redirector is expected to resolve lock conflicts. Loading SHARE has no effect on a redirector. The redirector must do all arbitration itself; this is obvious in the case of a true network redirector, which must keep all state at the server.

3 This function only provides locking in DOS 3.1–3.3 with parameters in registers and on the stack. Both locking and unlocking are achieved through this subfunction in DOS 4.0+, and locking with parameters in the LOCKREC structure.

```
Subfunction 0Bh
Unlock Region of File
Inputs:         ES:DI -> SFT for file
                CX:DX = region offset
                SI = high word of region size
                Word at top of stack = low word of region size
Outputs         Carry set, error code in AX if error encountered
```

1 See note 1 for subfunction 0

2 The redirector is expected to resolve lock conflicts

3 This subfunction is only called in DOS 3.1–3.3 and is superseded by subfunction 0Ah BL=1 in DOS 4.0 and higher

```
Subfunction 0Ch
Get Disk Space
Inputs:         ES:DI -> CDS for drive
Outputs:        AL = Sectors per cluster
                BX = Total clusters
                CX = Bytes per sector
                DX = Number of available clusters
```

1 The redirector should not compare the supplied CDS pointer in ES:DI *not* in the SDA as with subfunction 0Eh with the address of the CDS for its drive or, preferably, the CDS contents with the contents of its own CDS to determine if the call is intended for its drive(s).

2 The units of sector and cluster are DOS arbitrary and may not be appropriate to the redirector's underlying storage. It is sufficient to return values such that (AL*CX*BX)

reflects the size in bytes of the drive as the redirector wants it reported, and that AL*CX*DX reflects the amount of free space in bytes that the redirector wants reported as available. The register usage here limits the size of redirector drives to 1,024 gigabytes.

```
Subfunction 0Eh
Set File Attributes
Inputs:         SDA.FN1 = Fully qualified filename
                SDA.CURR_CDS -> CDS for drive with file
                Word at top of stack = New file attributes
Outputs:        Carry set, error code in AX if error encountered
```

See note for subfunction 01h.

```
Subfunction 0Fh
Get File Attributes
Inputs          SDA FN1 = Fully qualified filename
                SDA CURR_CDS -> CDS for drive with file
Outputs         Carry set, error code in AX if error encountered
                If no error, AX = file attributes
                BX:DI = file size
```

1 See note for subfunction 01h.

2 INT 21h AH=23h "Get File Size" depends on the BX:DI file size return value.

```
Subfunction 11h
Rename File
Inputs          SDA.FN1 = Current fully qualified filespec
                SDA FN2 = New fully qualified filename
                SDA CURR_CDS -> CDS for drive with file
Outputs         Carry set, error code in AX if error encountered
```

1 See note for subfunction 01h.

2 The redirector can use the SRCH_BLK, FOUND_FILE_REN, SRCH_FILE, and REN_FILE fields of the SDA as a workspace for iterating over source and target filespecs.

```
Subfunction 13h
Delete File
Inputs:         SDA.FN1 = Fully qualified filespec
                SDA.CURR_CDS -> CDS for drive with file
Outputs         Carry set, error code in AX if error encountered
```

1 See note for subfunction 01h.

2 The redirector can use the SRCH_BLK and FOUND_FILE fields of the SDA as work space for iterating over source and target filespecs.

```
Subfunction 16h
Open Existing File
Inputs:         SDA.FN1 = Fully qualified filename
                SDA.OPEN_MODE = Open mode for file
                SDA.CURR_CDS -> CDS for drive with file
                ES:DI -> Uninitialized SFT for the file
Outputs:        Carry set, error code in AX if error encountered
                SFT completed if no error
```

1 See note for subfunction 01h.

2 The redirector should not set the OPEN_HANDLES field in the SFT; DOS maintains this field itself.

3 Bit 6 of the open mode will be set for an FCB open.

```
Subfunction 17h
Create/Truncate File
Inputs:         SDA.FN1 = Fully qualified filename
                ES:DI -> Uninitialized SFT for the file
                SDA CURR_CDS -> CDS for drive with file
                Word at top of stack = File attribute for file
Outputs         Carry set, error code in AX if error encountered
                SFT completed if no error
```

1 See note for subfunction 01h

2 INT 21 - AH = 5Bh Create New File calls this subfunction for 5Bh to fail if the file already exists with the intent [The caller must be able to communicate the pre-existence of a file to applications that check by *failing* the value at the top of the stack

3 The redirector should not set the CALLER'S field in the SFT DOS maintains this field itself

```
Subfunction 18h
Create File without CDS
Input and Output  Identical to subfunction 17h (see above)?
```

Calling INT 21 - AH = 5Bh Create New File with a UNC filename such as "\\PC\DOSBAR" triggers DOS 4+ to subfunction 18h It is similar to subfunction 17h but is only called when the current CDS pointer for the drive has an offset of FFFFh (see also subfunction 19h) This call may have been added to support LAN Manager named pipes

```
Subfunction 19h
Find First without CDS
Input and Output  Identical to subfunction 18h (see below)
```

Like subfunction 18h, this allows redirectors to manage virtual files on drives without a CDS DOS calls this function in its Find First code when the current CDS has an offset of FFFFh

```
FDC8:6C22   C43EA205        LES DI,[05A2]   ; current CDS
FDC8:6C26   83FFFF          CMP DI,-01      ; offset  FFFFh
FDC8:6C29   75D6            JNZ DO 2F 111B  ; do regular redir call
FDC8:6C2B   B81911          MOV AX,1119     ; do no-CDS redir call
FDC8:6C2F   CD2F            INT 2F
FDC8:6C30   C3              RET
                    DO 2F 111B
FDC8:6C31   2617453D0080    TEST Word Ptr ES:[DI+45],8000 ; CDS network bit
FDC8:6C37   7406            JZ no redir
FDC8:6C39   B81B11          MOV AX,111B
FDC8:6C3C   CD2F            INT 2F
FDC8:6C3E   C3              RET
                    no redir
                    .
```

This call and thus the CDS offset FFFFh check and new call is triggered with a command such as "DIR \\PC\DOSBAR"

UNC Filespecs

Tim Farley

When a redirector is installed that supports the non-CDS calls, you can use UNC-style filespecs directly in DOS calls For instance, you could DIR \\SERVER1\VOL1*.* to search the root drive of the volume VOL1 on server SERVER1 Even though it is a front-end hook and not a redirector, the Novell NetWare shell (NETX) supports this behavior You can also

do this under many of the networks which are redirectors, including Artisoft's LANtastic. NetWare Lite 1.0, on the other hand, doesn't support a DIR of a UNC filespec.

The non-CDS calls can help if you know the exact network name of a file you need to access but don't want to set up a CDS entry for a fake DOS drive on which to access that file. Some of Novell's own utilities such as LOGIN.EXE use this trick.

Understanding UNC filespecs is crucial to writing a proper network redirector, especially when it comes to implementing the INT 21h AH=5Fh and AH=5Eh calls. Microsoft's *LAN Manager's Programmer's Reference* briefly discusses UNC.

```
Subfunction 18h
Find First Matching File
Inputs          SDA FN1 = fully qualified filespec for search
                SDA SDB = uninitialized Search Data Block
                SDA FOUND_FILE -> Directory info buffer for found file
                SDA SRCH_ATTR = Search attribute mask for file
Outputs         Carry set, error code in AX if error encountered
                If no error, SDB initialized
```

See note 1 for subfunction 01h.

```
Subfunction 19h
Find Next Matching File
Inputs          SDA SDB = Search Data Block from last Find operation
                SDA FOUND_FILE -> Directory info buffer for found file
Outputs:        Carry set, AX = 12h if no more files
```

The redirector should use the bottom 6 bits (mask 0x3F) of the DRIVE_NUM field of the SRCH_BLK in the SDA to determine whether the call continues a previous search on its drive number (0 = A:, 1 = B:, and so forth).

But this above is probably wrong. According to David Marken:

> I'm a novice logic and the corresponding mask with 3Fh work well lead to flaky results under IBM LAN Server. You may well get a situation where the Phantom will claim a findnext whose findfirst was handled by LAN Server. MSCDEX doesn't have this problem because it explicitly tests bit 6 (0040h) to be sure it's on before claiming the call. Masking with 3Fh will ignore that bit and thus mistakenly claim some calls for findnext's operating redirectors store a 1-based drive in the low 5 bits of the SDB drive byte field. LAN Server is a non-cooperating redirector that uses the low 6 bits in some other fashion thus requiring cooperating redirectors to distinguish themselves with bit 6 set. Cooperating redirectors identify themselves by setting bit 6 in the drive letter (this is the same bit that turns a 1-based drive into a drive letter A:/).

```
Subfunction 10h
Close all Files for Process
```

To implement this function the redirector must maintain a record of all files opened and by which processes on each machine. (This is a DOS broadcast called even if no drive in the CDS has the network attribute.) DOS calls this function immediately after using INT 21h AH=3Eh to close all of a terminating process' open files. The current PSP still points to the terminating process.

```
Subfunction 1Eh
Do Redirection
Inputs:         Word at top of stack = Command to execute (e.g., 5F02h)
                Other inputs depend on command to execute
Outputs         Carry set, error code in AX if error encountered
                Other outputs depend on command to execute
```

this call back end to INT 21h AH=5Fh. For example, if you want your redirector's drives to show up at INT 21h AX=5F02h assign list (see NETDRV.C, Listing 8-15), then you need to implement this call. To determine this call for an AX=5F03h Make Network Connection call, use the UserValue CVN (see "Another Detection Method"). LAN Manager also uses INT 21h AH=5Fh (see *Dr. Dobb's Journal*, April 1993).

```
Subfunction 15h
Printer Setup
Inputs          Word at top of stack = Command to execute (e.g., 5E02h)
                Other inputs depend on command to execute
Outputs         Carry set, error code in AX if error encountered
                Other outputs depend on command to execute
```

DOS calls this subfunction for INT 21h AH=5Fh, similar to the way that 21/111E is the back end to 21/5F.

```
Subfunction 20h
Flush All Disk Buffers
Inputs & Outputs:               Unknown
```

This is a DOS broadcast: when the Reset Drive function (INT 21h AH=0Dh) is called, DOS calls INT 2Fh AX=1120h, even if no CDS has the network bit set.

```
Subfunction 21h
Seek From End of File
Inputs:         ES:DI -> SFT for file
                CX:DX = Offset relative to end of file to position to
Outputs         Carry set, error code in AX if error encountered
                DX:AX = new file position
```

This function is almost never called in DOS 4.0 and higher, so don't depend on it to keep you informed of file position changes. The redirector should always use the SFT DOS field in the SFT to determine the current file position at which to read or write. As seen in Chapter 6, given an INT 21h AH=42 hook, DOS almost always fiddles directly with the SFT without calling the redirector. Subfunction 21h gets called only by a program's use of method #2 move from end, and even then only for up to 16 bytes when certain SHARE open access flags permit write access. The conditions under which this subfunction is called are so specialized that it appears to have been a special purpose hack.

```
Subfunction 22h
Process Termination Hook
Input:          DS = PSP of process about to terminate
```

Whenever a program exits, DOS issues this subfunction 22h broadcast. The following small INTRSPY script hooks this call to compile a list of programs that have terminated:

```
intercept 2fh function 11h subfunction 22h
    on_entry output (ds : 8 >byte,asciiz,8)   (PSP   ds   ) exiting
```

This might help a TSR that must know when programs exit. Trapping subfunction 22h is far easier than hooking INT 21h, INT 20h and INT 27h, which is how a front end hook would watch for process terminations.

```
Subfunction 23h
Qualify Path and Filename
Inputs          DS:SI  > Unqualified filename
                ES:DI -> Buffer for fully qualified filename
Outputs         Carry set, error code in AX if error encountered
```

DOS appears to support a default name qualification function that does a very adequate job without support from a redirector. DOS appears to need the assistance of this redirector function only for some very special directory or filename translations. The output of this function, or of the DOS

default routine directly supplies the input for the directory and file subfunctions. This call is a DOS broadcast made even if no redirector is running.

```
Subfunction 24h
Turn Off Remote Printer
```

Called by DOS 5.1+ kernel if subfunction 26h below returns carry set.

```
Subfunction 25h
Redirected Printer Mode
Inputs          Word at top of stack = Command to execute (e.g., 5007h)
                Other inputs depend on command to execute
Outputs         Carry set, error code in AX if error encountered
                Other outputs depend on command to execute
```

DOS 4 uses a call to INT 21h AX=5D07h Get Redirected Printer Mode, AX=5D08h Set Redirected Printer Mode, or AX=5D09h Flush Redirected Printer Output, into a broadcast of subfunction 25h. Unless an INT 2Fh handler supports this subfunction, these INT 21h calls perform no action.

```
Subfunction 26h
Remote Printer Echo On/Off
Inputs:         ES:DI  > SFT for file handle 4 (stdprn)?
                ???
Outputs:        CF set on error
```

DOS calls this subfunction when print echoing ("^P" "PrtSc") changes state and stdprn has bit 11 ("network spooler") of the device information word set in the SFT.

```
Subfunction 27h
Remote Copy
Inputs          SI = Source file handle
                DI = Destination file handle
                DX:CX = Bytes to copy (from/to current seek positions)
                BX = 'NW' (5746h) signature for NetWare
Outputs         CF clear if successful, set if failed
                AX = Return code, if error
                     05h Access denied  No read rights or no write rights
                     06h Invalid handle  One of the file handles is invalid.
                     08h Invalid format  Improper signature in BX
                     11h Device not the same: Both files are not handled by
                         the redirector.
                     38h Unexpected network error.
                If successful, current file positions updated for both files
```

While not specified, it seems to be Novell-specific; this function copies one file to another file where both files are on the redirected drive. This can greatly reduce network traffic. This function does not rely on but is called from within DOS and can therefore be called directly from an application. Unlike all other file access subfunctions, this function is passed file handles, not SFT pointers.

The Remote Copy call function appears to be supported in Netware 4.0; the beta documentation for which provided the basis for the above description. Microsoft LAN Manager has a similar NetRemoteCopy function (INT 21h AX=5F44h).

```
Subfunction 2Eh
Extended Open File (DOS 4+)
Inputs:         SDA FN1 = Fully qualified filename
                ES:DI => Uninitialized SFT for the file
                Word at top of stack = File attr for created/truncated file
                SDA SPECOPEN_ACT = Action codes
                SDA.SPECOPEN_MODE = Open mode for file
Outputs         Carry set, error code in AX if error encountered
                SFT completed if no error
                CX = result code
```

```
01h file opened
02h file created
03h file replaced (truncated)
```

1. See note for subfunction 01h
2. DOS 4.0 introduced this function to provide a unified interface to the functionality supplied by subfunctions 16h and 17h and to support DOS Function 6Ch
3. The redirector should not set the CURRENT_PSP field in the SFT; DOS maintains this field itself

There are other INT 2Fh AH=11h functions that are not part of the network redirector interface. For example, the LAN Manager API for DOS provides asynchronous named pipes using INT 2Fh AH=11h calls. For more information, see Michael Shiels, "The Undocumented LAN Manager and Named Pipe APIs for DOS and Windows," *Dr. Dobb's Journal*, April 1993 (this appeared in the *DDJ* "Undocumented Corner").

Using DOS Internal Functions

Because redirectors effectively become part of DOS, they have at their disposal many of the same functions that DOS itself uses internally. As we saw in Chapter 6, DOS uses INT 2Fh AH=12h to export many DOS internal routines. This interrupt-based interface was probably initially designed for, or at least thrown together for, use by redirectors and presents a wealth of quite useful functions that are only accessible to redirectors and other DOS subsystems.

Phantom uses only three DOS internal (DOS) functions and the only mandatory one is Set SFT Owner (INT 2Fh AX=1208h). As stated above, one of the benefits of the redirector interface is that it hides with one exception the existence of the two DOS file access methods (FCB vs. handle based) available to DOS programs. The only exception is that at file open time the redirector must call Set SFT Owner for FCB opens (bit 13 set in the open mode word in the SFT passed to the redirector open call). INT 2Fh AX=1216h (see above) indicates an FCB open. Failure to call this function in this situation leads to "FCB unavailable" errors.

Phantom also calls Get Date and Time (INT 2Fh AX=1200h) to obtain the system date and time in DOS directory format. It could equally well convert the BIOS timer tick count value for the time and the CMOS RAM and XT-1980 clock/calendar for the date to generate the necessary values for new files or file time stamping, but the DOS internal function is slightly simpler.

Finally, Phantom calls Check If Char Device (INT 2Fh AX=1223h) to detect file access to NUL, CON, and so on, which DOS does not filter out before passing control to a redirector. Without this check, Phantom would mistakenly treat users' or applications' files with names such as NUL and CON.

The following is a list of the INT 2Fh AH=12h subfunctions that a DOS-level file system redirector might use. The entries do not describe usage or data (see the Appendix or the Interrupt List on disk), but instead discuss why a redirector might want or not want to use the function.

- 06h Invoke critical error

This is potentially a very important function for a redirector that relies on a physical, network, or other possibly error-prone medium. It triggers the mechanism that leads to invocation of the documented Int 24h critical error handler. There are two requirements for its proper use:

- Set the appropriate error class, locus, and suggested action. These are happily accessible in the ERR_LOCUS, ERR_CODE, ERR_WHAT2DO, and ERR_CLASS fields in the SDA.
- Create a dummy device driver header for the drive and record its address in the DEVDRVR_PTR field of the SDA. This is required because DOS uses the device attributes word of the device driver associated with the error to decode the type of error message to display.

Errors generated during open, read, write, close and findfirst/findnext processing are candidates for critical error invocation. Because Phantom does not use an unreliable medium, in general a safe assumption about XMS, especially given well known bugs in the XMS resize function, it has no need for critical error capabilities.

However, the code fragment in Listing 8.38 shows modifications that might be made to readfil() if PHANTOM.C had a failure at read time were possible. This code fragment assumes that read_fata() now returns an int indicating success (non-zero) or failure (zero). This code is an alternate to the version of readfil() shown earlier in Listing 8.30.

Listing 8.38: Alternate Version of readfil() to Handle Critical Errors

```
// Possible returns from critical_error()
#define CRITERR_IGNORE      0
#define CRITERR_RETRY       1
#define CRITERR_ABORT       2   //ABORT returns control to DOS, not us
#define CRITERR_FAIL        3

uint sp_before_switch;          // save area for our sp

// This is the dummy device driver header to keep DOS happy at
// critical error invocation. In this case, the critical error message
// will be 'Error reading drive D:'. Change the dev_attr field value
// from 0 to 0x8000 to generate 'Error reading from PHANTOM'
structure {
    long    next_hdr;
    uint    dev_attr,
    uint    strat_entry, intr_entry;
    char    dev_name[8],
    } dummy_devhdr = {-1,0,0,0,{'P','H','A','N','T','O','M',' '},

//Set DOS extended error info.
void set_dos_extended_err(uint ax_val, uchar bl_val, uchar bh_val,
    uchar ch_val)
    {
    //  ax_val -- DOS extended error code
    //  bh_val -- error class
    //  bl_val -- suggested action
    //  ch_val -- locus of error
    ((V3_SDA_PTR) sda_ptr)->err_code   = ax_val,
    ((V3_SDA_PTR) sda_ptr)->err_action = bl_val,
    ((V3_SDA_PTR) sda_ptr)->err_class  = bh_val,
    ((V3_SDA_PTR) sda_ptr)->err_locus  = ch_val,
    ((V3_SDA_PTR) sda_ptr)->devdrvr_ptr = (void far *) &dummy_devhdr;
    }

//Invoke DOS critical error handler and get user
//  return code (Ignore, Retry, Abort, Fail).
int critical_error(uchar ah_val)
    {
    int ret;

    //Invoke critical error.
     asm {
        mov ah, ah_val
        push bp
        push si
        push di
        mov di, 0008h                   // Read error
        mov bp, ds                      // BP:SI must point to our fake
        mov si, OFFSET dummy_devhdr //  device header
        mov sp_before_switch, sp        //Save current stack pointer
        cli
        mov ss, dos_ss                  //Establish DOS's stack, which was
        mov sp, dos_sp                  //  current when we got called.
        sti
```

```
        mov al, our_drive_no        //Driveletter
        push ax                     //Int 24h AX value goes on the stack
        mov ax, 1206h               //Invoke critical error.
        int 2Fh
        mov bx, ds                  //Restore our stack segment (same as DS)
        cli
        mov ss, bx
        mov sp, sp_before_switch    //  and stack pointer (which we saved).
        sti
        pop di
        pop si
        pop bp
        xor ah, ah
        mov ret, ax
        }
    return ret;
    }
void read(r,(void)                  // Read from file - subfunction 08h
    {
    SFTREC_PTR p = (SFTREC_PTR) MK_FP(r.es, r.di);
    if (p->open_mode & 1) { fail(5); return; }

    if ((p->file_pos + r.cx) > p->file_size)
        r.cx = (uint) (p->file_size - p->file_pos);

    if (!r.cx) return;

    /* Fill caller's buffer and update the SFT for the file */
    while (read_data(&p->file_pos, &r.cx,
            ((DOS_SDA_PTR) sda_ptr)->current_dta,
            p->start_sector, &p->rel_sector, &p->abs_sector) == 0)
        {
        set_dos_extended_err(   0x001E,  // Error - Read fault
                                0x04,    // Action - Orderly abort
                                0x0B,    // Class - Media error
                                0x05),   // Locus - Memory

        // call the user's critical error handler. This is interesting
        // because we are used to seeing critical error from the app's
        // point of view; here we see it from DOS's point of view.
        switch (critical_error(1111110b)) //  0 -  0 indicates read
                                          //  1,2    11 indicates file error
                                          //  3    1 indicates allow fail
                                          //  4 -- 1 indicates allow Retry
                                          //  5 -  1 indicates allow Ignore
            {
            case CRITERR_IGNORE: break;
            case CRITERR_FAIL  fail(2), return, // not reached
            case CRITERR_RETRY  break,
            default: break, // Impossible...
            }
        }
    }
```

If read() encounters an error it first calls set_extended_error to set the appropriate codes into the SDA and then calls the critical error function with flags to indicate where the error occurred and what responses are to be allowed. These bits together with the extended error class, action, and locus values are documented in the DOS programmer's reference for INT 21h AH=59h Get Extended Error. The return from critical_error() is the user or application's response to the error.

Although CRITERR_ABORT is defined we never receive control back if that is the selected response. DOS fails the application or command immediately after the Int 24h handler returns.

As a final note on critical errors, redirectors should use the INT 2Fh AH=05h interface to expand critical error messages. For example, MSCDEX uses this interface. There is a detailed discussion of this interface and other error handling issues in Chapter 17 of Geoff Chappell's *DOS Internals*.

- 08h Decrement SFT Reference Count

Redirector subfunction 6 (Close File) must decrement the SFT handle count to avoid creating orphaned locks. INT 2Fh AX=1208h does just this. However, it is much more efficient to decrement the SFT reference count directly rather than to call this function. For example, the following is lifted from the Phantom's clsfil function:

```
SFTREC_PTR p = (SFTREC_PTR) MK_FP(r.es, r.di);
if (p->handle_count)            /* if handle count not 0, decrement it */
  --p->handle_count;
```

- 0Ah Perform Critical Error Interrupt

This function is similar to the preferable function 06h. The function 0Ah version appears to need a DPB for the redirected drive. In general, redirector drives don't prepare DPBs.

- 0Bh Signal Sharing Violation To User

Peer-to-peer DOS networks and SHARE.EXE use this function to signal that a command or application has attempted to open a file previously opened by FCB or with a sharing mode. Its principal return is the value of the carry flag, indicating whether to retry the operation.

- 0Ch Set SFT Owner (Set FCB Owner)

As I've noted earlier, this is the one essential DOS internal call for a redirector. While DOS internally uses it on all of the time, a redirector only needs it for FCB opens, so it's sometimes called Set FCB Owner. Clearly, the function sets the specified SFT owner to the value of the current PSP. But it appears to do a good deal more than that, based on the behavior of MSCDEX. A redirector may have to modify the open mode before calling Set SFT Owner; see the stub at Listing 8-34 and set_sft_owner() in PHANTOM.C on disk.

- 0Dh Get Date And Time

This service function returns in AX/DX the current date/time in packed DOS directory format. It can get a time/date stamp for a new directory entry generated when, for example, a subdirectory is created or to which a newly created file is flushed or closed. Phantom uses this in mid_sft (see Listing 8-34).

- 11h Normalize ASCIZ Filename

This function translates a filename from an input buffer into an output buffer, turning forward slashes in the input buffer into backslashes in the output buffer and transferring all other characters unchanged.

- 16h Get Address Of System File Table (SFT) Entry

This function accepts an SFT entry *number* and converts it into an SFT *address*. The SFT entry number is retained in the PSP for a process at the index for the appropriate handle. Since almost all redirector services accept an SFT entry rather than a file handle, this function, together with function 20h, is a fundamental tool for a redirector which supports Int 21h function 53h subfunction 27h Remote Copy, which is passed file handles rather than SFT addresses.

- 18h Get Caller's Registers

This is a potentially useful function for a redirector that wants to know more about the originating DOS call. It returns a pointer to the saved register contents upon entry to the DOS function dispatcher. See the lengthy discussion of this function in Chapter 6.

- 1Ah Get File's Drive

Given a fully qualified filespec, this function separates the path from the drive letter and returns the drive number to which it refers. It could help a redirector that uses a standard DOS drive identification string (a drive letter immediately followed by a colon). The typical use for this function could be in Phantom's obstructive device driver that disallows use of this unsophisticated function. To determine whether the path is relative to a specific drive and not to the default drive, substitution 1Ah looks for a colon in the second character position. DOS uses it to parse paths at the INT 21h level.

- 1Bh Compare Filenames

This function compares filenames, ignoring case and treating forward and back slashes as equivalent. It could help if the redirector's underlying file system has a UNIX flavor. (Most of the rest of DOS does not.) And it is expensive. You can even pass forward slashes to INT 21h, as do some programs such as PKZIP.

- 1Fh Make Current Directory Structure Invalid

This function invalidates the CDS referenced by the DRIVE_CDSPTR field of the SDA. To achieve this it simply moves 0 to the FLAGS field of the CDS entry. If a redirector encounters a fatal error, this function provides a simple way of invalidating its drive since DRIVE_CDSPTR is already appropriately set.

- 20h Get Job File Table Entry

This function, when used together with subfunction 06h, provides a mechanism to convert from a file handle, through a process's current process to an SFT entry address. This helps a redirector that supports Int 21h/ah=5Dh (see subfunction 2Ch, Remote Copy).

- 22h Set Extended Error Info

This subfunction provides a means for modifying the DOS internal associations between an extended error code and its associated class, action and locus fields. Phantom sets this information directly into the SDA, which appears to be more reliable than subfunction 22h when more than one redirector is present on the machine. With subfunction 22h, one redirector might override modifications made by another. MSCDEX, however, uses this subfunction.

- 23h Check If Character Device

This subfunction walks the device driver header chain searching for a character device with the name specified in the DOS_INT field of the SDA. Phantom uses this function to weed out and fail any calls that attempt to create a file or subdirectory with the same name as a character device such as CON or AUX. DOS drivers out redirectors to these only if no explicit path is included.

- 26h Open File

This function, together with functions 27h, 28h and 29h, has the useful capability of performing read-only file access from within a redirector. It is interesting and perhaps disappointing that there is no Write To File function in the group. MSCDEX, which of course is read only, uses these functions. This provides the means to read configuration files on the fly. This function consumes an SFT entry and a JFT entry in the current PSP.

- 27h Close File

Closes a file belonging to the current PSP. This might be a file opened using function 29h.

- 28h Move File Pointer

Performs a seek within the specified file, which belongs to the current process and which may have been opened using function 26h.

- 29h Read From File

Performs a read from the specified file, which belongs to the current process and which may have been opened using function 26h. This call modifies the CURRDTA field of the SDA. If this call is made from within a redirector read or write call, the redirector should save the current contents of the CURRDTA area before this call and restore it afterwards.

The Future of the DOS File System

As we said at the beginning of this section, Microsoft introduced the redirector interface in DOS 3.10. In DOS 6.0 it is still in place, little changed, and Phantom works in preemptive versions of DOS 7.0 from Chicago, too.

However, the redirector's future looks a little confused. Microsoft with the introduction of Windows for Workgroups has moved from the REDIRFSD.ASM interface to a Windows virtual device driver, VREDIR.386, to implement their redirector. This redirector traditionally translates between the redirector interface and the Server Message Block (SMB) protocol on which many PC peer-to-peer networks are based. On the other hand, in other network related areas of Microsoft development there is apparently a move away from the redirector interface, presumably because of the relatively poor level of interrupt 21h support in that area, or perhaps because of the increasing length of the INT 21h chain, toward an INT 21h call intercept replacement strategy that we advised against at the beginning of the section!

The giant of the network operating system marketplace, Novell, has been taking the opposite approach. In NetWare 4.0 the workstation component, NETX.COM (or NETX.EXE in previous versions), consists of several modules, loaded by VLM.EXE, which is the Virtual Loadable Module manager. One of the modules that it manages is REDIRVLM, a DOS redirector. For backward compatibility, Novell provides NETX.VLM, which provides the traditional INT 21h replacement enhancement functionality (see Chapter 4).

The difference between these two approaches suggests several possible alternative views. The most pessimistic is that Microsoft is in the process of phasing out the redirector interface, that VREDIR.386 simply represents a platform for increasing the support for Windows and networking, and that it will soon host an entirely different file system interface. This would imply that Novell (and the authors of Ralph) does not realize this and has potentially wasted a lot of time and development cost on a lame duck.

It is possible that Microsoft is indeed wary of encouraging use of the redirector interface because of its rather messy past and backwater support status, but that it will continue to tolerate it—a view which would endorse Novell's strategy of making workstation file system interface modular—but it still leaves uncertainty.

One might, from a more optimistic perspective, conclude that the redirector interface is not only to remain in existence, but that, through guesswork or information, Novell expects the level of support for it to increase.

All of this is part of larger changes in the implementation of the DOS file system. Just as WW includes VREDIR.386, Microsoft also has VFAT.386, a 32-bit protected mode Windows virtual

device driver supporting the FAT file system. VFAT.386 is part of Microsoft's Chicago project (DOS 7.0, Windows 4.0), but it is appearing early in WfW 3.11, along with VREDIR, VSHARE, and other file system VxDs. As noted earlier, Chicago will also introduce an IFSMGR as the documented, improved, and approved way of writing installable file systems.

In addition to talking a lot about the FAT, directory, CDS, SFT, IFT, DPB, System FCBs, and so on, one central point emerges from this ridiculously lengthy chapter. The DOS file system isn't just for physical disks anymore. Any file system is primarily a logical rather than a physical construct. Interfaces such as the redirector have steadily moved the DOS file system away from the mundane world of cylinders, tracks, sectors and toward a more abstract notion of file store. A disk, directory, or file is anything that behaves like one.

CHAPTER 9

Memory Resident Software: Pop-ups and Multitasking

by Raymond J. Michels

With the release of MS-DOS 5.0, Microsoft documented many previously undocumented DOS functions [illegible] TSR related functions. Not only are these functions documented for DOS 5.0, they are also documented back to the version of DOS where they first appeared. Some programmers used [illegible] but because these functions were undocumented it was unsafe to use them. In retrospect [illegible] have been unsafe. By using these undocumented [illegible] developers pushed Microsoft into documenting and supporting them. [illegible] undocumented [illegible] is automatically safe.

[illegible] DOS with which PC programmers are generally familiar [illegible] resident programs, because [illegible] by DOS Terminate and Stay Resident (TSR) [illegible] INT 21h Function 31h, or the older TSR interrupt INT 27h. [illegible] TSRs. However, these [illegible] writing TSRs [illegible] INT 21h DOS [illegible] PC programmers [illegible] must use [illegible] DOS [illegible] of TSRs.

[illegible] on the [illegible] it is not [illegible] DOS [illegible] TSRs. Microsoft [illegible] Richard Wilton's "Terminate and Stay Resident [illegible]" in the massive *MS-DOS Encyclopedia*. Wilton's article discusses the following undocumented DOS functions and interrupts:

- INT 21h Function 34h (Return InDOS Pointer)
- INT 21h Function 50h (Set PSP Segment)
- INT 21h Function 51h (Get PSP Segment)
- INT 21h Function 5D0Ah (Set Extended Error Information)
- INT 28h (Keyboard Busy Loop)

These functions are now documented in Microsoft's *MS-DOS Programmer's Reference*. In addition, several books on [illegible] programming for the PC [illegible] include generic TSRs that use [illegible] DOS functions. The popular [illegible] published for each issue of *PC Magazine* [illegible] TSRs [illegible] assembly listings [illegible] show the [illegible] of using these DOS functions.

[illegible] that provide generic TSR [illegible] are also available. These [illegible] DOS [illegible] applications [illegible]. Anyone [illegible] TSR [illegible]. [illegible] and tested routines [illegible] TSR [illegible] which would otherwise [illegible]. Some of the commercial TSR libraries available are as follows:

- TesSeRact Ram Resident Development System (TesSeRact)
- CodeRamaR for C or assembler (Microsystems Software, Framingham, MA)
- "resident C" (Hold Everything and TSRUtil, South Mountain Software, South Orange, NJ)
- C Tools Plus 6.0 (Blaise Computing, Berkeley, CA)
- TSRs and More (C/C++, TurboPower Software)
- Object Professional 1.0 (Turbo Pascal 5.5, Turbo Power Software)
- Magic TSR Loader (for ASM, Quantasm Corporation, Cupertino, CA)
- Stay Res Plus (for BASIC, Micro Help)
- BATCOM (batch file compiler with TSR option, Wenham Software, Wenham, MA)

In addition, if Pascal is your favored language, check out the source code for Tim Kokkonen's excellent MARK and RELEASE programs available on CompuServe (GO BPROGA).

Is there one right way to say on this subject? Simply, no. Several areas of TSR programming which are fundamental DOS have not been adequately covered elsewhere. These include

- INT 21h Functions 5D06h–5D0Bh (Get DOS Swappable Data Area)
- Effective TSR termination
- Using C (both Microsoft and Borland) interrupt functions
- Writing pop up TSRs

In addition, the Task Switching APIs provided by Windows and DOSSWIT.EXE (though undocumented) are new enough to require some mention here. We'll touch upon their use in TSRs for solving the "instance data" problem and for dealing with task switches.

Many tasks (or what a TSR was once suitable, should today perhaps be instead carried out by a Windows virtual device driver (VxD; see the end of Chapter 3). In addition, there are now several computing standards (including protected mode TSRs; these are discussed briefly in Chapter 4 (see the section on "Protected Mode DOS").

This chapter presents a generic TSR skeleton that you can use ("TSRify" your own programs, using either Borland C++ version 3.xx or Microsoft C version 6.0 or higher. You can use this generic TSR to transform some other parts of this book into pop-ups that are activated by the press of a user-defined hot key. We'll discuss these techniques in a moment. The last section of this chapter presents a memory resident program that is not activated by a hot key, instead it is periodically activated by the PC's internal clock. It can be quite useful for multitasking in the background with whatever programs you run from the DOS command line (the foreground). The program is an add-on to the PRINT multitasking TSR that comes with DOS.

TSR: It Sounds Like a Bug, But It's a Feature

Only three functions are absolutely necessary to write memory resident software for MS DOS; these three functions have since been documented since their inception. They are:

- Terminate and Stay Resident (INT 21h Function 31h)
- Set Interrupt Vector (INT 21h Function 25h)
- Get Interrupt Vector (INT 21h Function 35h)

A TSR is any DOS program that calls INT 21h Function 31h (or the obsolete but equivalent interrupt INT 27h). In a description from Microsoft on its purpose in the IBM DOS 3.3 Technical Reference, it "terminates the current process and attempts to set the initial allocation block to the memory size in paragraphs. Does not close files. The TSR function is very much like the normal DOS termination function (INT 21h Function 4Ch), which kills off whatever program calls it. The difference is that after calling the TSR function, all memory belonging to the program *is not* released

Instead, part or all of the program's memory allocation block is preserved so that it will not be overlaid by the next program to be loaded.

Thus a TSR is a new DOS program that leaves bits of itself behind after terminating. This sounds like a classic bug—sometimes referred to as the "leaky bucket" where memory is allocated and then never deallocated. It doesn't sound like a feature you would want in your operating system, but one area in which memory-resident software substantially contributes to bulk.

What is the advantage of terminating without freeing all your memory? It saves time and some effort. Once a program is running, there's not much your memory is going to do other than take up space. Giving up memory can occasionally serve a purpose. Utilities like TSRs have been written with names like MEMHOG and EATMEM to allow developers with say a 640K machine to test software under conditions similar to those on say a 512K machine. But aside from this limited use, what good is it to program memory after you're gone. You can't take it with you!

This is where the second necessary function, Set Interrupt Vector, comes in. All machines based on the Intel 80x86 architecture allow any program to install code that gets invoked whenever a hardware or software interrupt is generated. For example, the code to service INT 21h is a gateway to MS-DOS services. That interrupt vector 21h points to code inside DOS that provides these services. The ability to name a piece of code to all of any interrupt vector is what makes the TSR function something other than a declarative way to consume memory. You can use the Set Interrupt Vector function to point interrupt vectors at your code and then call the TSR function to keep this code and its associated data and stack space resident in memory after you terminate. Whenever one of your interrupts is generated, it activates the code you left behind. Thus there really is life after termination—you can take it with you!

What sort of interrupts would a TSR be interested in trapping. There are two choices: one is the hardware interrupt INT 9 generated every time a user presses a key. By trapping INT 9 a TSR can watch every keystroke but it never replaces (intercepts) it. Thus TSRs are often more resident cousins of device-driver programs that process input from *The Wizard* activates the user presses Alt-M or *The Phantom Phone* answers whenever the user presses Alt-P. These are the only two keys the TSR is interested in and they are referred to as the program's hotkeys. Each time the user hits a key the INT 9 handler wakes up looks at the key and if it is not one of its hotkeys goes back to sleep. But if it is one of its hotkeys then your application-specific code takes over. In this example that means paying Ivan Ogre's ransom. Unfortunately, in TSRs in general this sudden switch in processing can be quite disconcerting to the poor user.

Now one item has been glossed over. What if the user types a key that is *not* one of the TSR's hotkeys. How does the key get to its intended target. The TSR can't just discard it or it appears somehow to other programs as a crash of the TSR does this by jumping to whatever interrupt previously was in the INT 9 vector before our TSR was. That is INT 9 handler. In other words before setting up your interrupt vector, almost all TSRs have to get the interrupt vector's previous value using the DOS Get Interrupt Vector function. Thus the TSR looks something like this:

```
INTERRUPT PTR old_int9_handler;
INTERRUPT my_int9_handler()
    IF (key == alt_m)
        m_kado();
    ELSE IF (key == alt_p)
        penzance();
    ELSE
        JMP PTR old_int9_handler();
BEGIN
    old_int9_handler = _dos_getvect(9), // INT 21h Function 35h
    _dos_setvect(9, my_int9_handler),   // INT 21h Function 25h
    go_tsr(),                           // INT 21h Function 31h
```

1 every program that has hooked INT 9 takes care to call the interrupt's previous owner, then every program that needs to will get a peek at the stream of user keystrokes. Jumping to the previous owner is the way of invoking the interrupt and the end result is an interrupt chain (see the INTCHAIN program at Chapter 6). Every time you press a key, a whole host of programs might see it. This mechanism for multiple program access to the keyboard input stream was formalized in the OS/2 concept of the "monitor."

There is a subtle choice between CALLing the previous interrupt handler and JMPing to it. Handlers that want to process an interrupt *after* the previous handler (i.e., postprocessing) pass control to the previous handler with a CALL. Otherwise, the handler preprocesses the interrupt and passes control with a JMP. Unlike a CALL, a JMP of course does not return.

While the best-known TSRs such as Borland's now-ancient Sidekick are pop-ups that are activated by hotkeys, pressing a hotkey is just one way of generating an interrupt. Anything that generates an interrupt can activate a TSR. For example, when your own program calls INT 21h, it is generating a software interrupt, so a TSR could easily attach itself to INT 21h, providing a mechanism for extending the operating system or for debugging, as in the INTRSPY TSR in Chapter 8. For example:

```
INTERRUPT PTR old_int21_handler,

INTERRUPT my_int21_handler()
    IF (ah = some function I'm interested in)
        // do pre-processing
        // maybe CALL PTR old_int21_handler()
        // do post processing
    ELSE
        JMP PTR old_int_21_handler(),

BEGIN
    old_int21_handler = _dos_getvect(0x21);
     dos_setvect(0x21, my_int21_handler),
    go_tsr(),
```

In this example, as soon as we attach our handler to INT 21h by calling _dos_setvect, the processor passes all INT 21h calls to the code in our handler. This means that our own calls to INT 21h from our TSR must be carefully first processed in our handler. It's best to keep up to the code in our handler to create problems with each INT 21h request. Presumably, the call to Function 31h would pass by unchanged to the original int 21h handler, which might be MS-DOS or some other TSR that previously hooked INT 21h, such as one of the simple application swappers from the end of Chapter 2.

What this power does is ensure that programs reserve the TSR facility for genuinely useful code that is worth having resident in memory. Software that helps the user prepare, assist with, and test a call for example, is not a good candidate for memory residency. Neither, for that matter, is our Concert and Score sample since readily available, dedicated hardware already exists for this purpose.

Where Does Undocumented DOS Come In?

Now that you know the functions you need to produce the TSR are all fully documented, where does undocumented DOS come in? Do you really need undocumented DOS to write a program that plays "I Am the Very Model of a Modern Major General" whenever the user presses the Alt-P hotkey? Unfortunately, you are not off the hook. Unless you have achieved remarkable data compression, you don't want to be one of the many occupying memory. Instead, when the user presses Alt-P, you want to allocate some memory, read the music in from a file, close the file, play the notes, free the memory, then go back to sleep.

It would be nice if things worked this way, but they don't. The problem is that in this example you have no control over when my_int9 handler will be invoked. Recall that my_int9 handler is not called from within the program; the way functions like _dos_setvect or go_tsr() are. Instead

int 9h" handler is called whenever the user pounds on the keyboard. A keypress is an asynchronous event that bears no relation either to the internal state of whatever program happens to be running or to the internal state of DOS. You can't control when the user will press a key.

For instance, the foreground program might be copying a large file to the printer when the user decides that it's time for a musical interlude. If while the foreground program is executing an INT 21h function such as Read File or Write File the pen2nace function suddenly takes over and starts issuing its own INT 21h requests, the resulting scenario is one which DOS was not designed to handle. MS-DOS is a single-tasking operating system which means that it does not allow for the possibility that it might be interrupted in the middle of one request be asked to carry out some other request and then resume the first request at the point where it was interrupted.

This property of MS-DOS is often referred to as "non-reentrance," meaning that if INT 21h is already executing, another INT 21h request can't be issued. A function or program which is "reentrant" is designed so that it can be interrupted at any time, allowing another process to enter without losing the state of the function just before the interruption. Primary among many techniques to achieve reentrancy is that a function will normally keep its state—the contents of variables that relate to a particular instance—on the caller's stack. With a very few exceptions, MS-DOS uses neither this nor any other reentrancy trick. As we saw in chapter 6, DOS relies almost entirely on global variables with its own stacks, rather than the caller's.

Any textbook on operating systems or on concurrent programming contains a discussion of the difference between reentrant code, which may be shared by several processes simultaneously, and what is correctly called serially reusable code, which may be used by only one process at a time. MS-DOS is serially reusable code.

When MS-DOS is called using INT 21h, DOS switches to one of three internal stacks: the I/O stack, the Disk stack, or the Xenix stack. Functions 00 through 0Ch use the I/O stack. The remainder of the functions use the Disk stack. If MS-DOS is called from a critical error such as DIR A: with the door open, the Xenix stack is used. In chapter 6, we saw exactly how DOS switches stacks. Because of this stack switching, if a TSR calls MS-DOS when the foreground is already executing inside INT 21h, MS-DOS loads the TSR's data onto its stack, overwriting the foreground process's data.

If DOS is in the process of servicing a function 0Ch request or lower and the TSR issues a function 0Ah (or lower or higher than that), there will be a problem because two different stacks are involved. In this case, as we again know from chapter 6, a few INT 21h functions (33h, 50h, 51h, 62h, and 64h) do not switch stacks. Because the caller's stack and all the buffers fully reentrant. But for the most part, DOS is not reentrant.

I've barely scratched the surface of the problems you must worry about. What if the heads on the hard disk are in the middle of writing data as part of the response to an application's INT 13h call? If the TSR starts issuing INT 13h requests that move the heads somewhere else, then you're going to lose. Reentrancy problem? That has nothing to do with stacks or reusable code, but that could well result in a scrambled hard disk.

Does this mean the TSR can't perform DOS memory and file operations whenever the user presses the hotkey? Essential files have to be done once during initialization, before hooking any interrupt vectors, so that the memory-resident portion of the TSR avoids all use of DOS calls. For example, one book on C programming for the PC makes the blanket statement that a TSR interrupt service routine "...cannot use any DOS functions." If this were true, I would certainly restrict what you can do with TSRs.

This isn't quite as terribly restrictive as it sounds. Many commercial programs for the PC that are TSRs bypass DOS for many operations such as screen display and keyboard input. Avoiding DOS is not only possible, but for certain key operations on the PC, it is practically a necessity. It is easy to write screen display functions, for example, that not only bypass DOS but which are many

times faster than DOS output routines and which provide far greater control over the screen. Not being able to execute DOS sounds almost like a blessing in disguise.

However, as we noted in Chapter 8, the one area of DOS functionality that nearly is irreplaceable is the I/O. Even a TSR can allocate expanded or extended memory rather than use the DOS memory allocation routines; expanded or extended memory is not always available, so many TSRs need to allocate memory through DOS. In summary, most TSRs need to make some INT 21h calls while popped up.

Fortunately, it is simply not true that TSR interrupt service routines "can't make INT 21h calls." But it is true that TSRs must do something special to make such calls. There are two options:

- Defer issuing INT 21h calls while INT 21h is in the middle of processing a request, or
- Somehow save and restore all of DOS's context, including the three DOS stacks, so that you can reenter it.

The second option will be discussed later in this chapter, in the section on the DOS Swappable Data Area (SDA). Until then, we will concentrate on how not to enter DOS in the middle of some other program's INT 21h call. But instead of wait until that call has completed, how to use DOS as a serially reusable resource. Until we discuss the SDA, you will be reading about the state that a TSR must save and restore as part of its pop-up regime.

The second point that here is to have some way of determining when INT 21h is busy or, more accurately, of detecting when one of its three stacks is in use. A short while ago, you saw a small block of code to trapping INT 21h calls and it may have occurred to you that this might help determine whether DOS is active. For example, you might put both the INT 21h handler and INT 9 handler into the same program and use the former to tell the latter whether it's safe to pop up.

```
INTERRUPT PTR old_int9_handler,     // keyboard
INTERRUPT PTR old_int21_handler,    // DOS
WORD using_io_stack = 0;
WORD using_disk_stack = 0;

INTERRUPT my_int21_handler()
    IF (ah <= 0x0c)
        INCR using_io_stack,
        CALL PTR old_int_21_handler;
        DECR using_io_stack,
    ELSE
        INCR using_disk_stack;
        CALL PTR old_int21_handler;
        DECR using_disk_stack,

INTERRUPT my_int9_handler()
    IF key == alt_m AND NOT using_disk_stack
        mikado();
    ELSE IF key    alt_p AND NOT using_disk_stack
        penzance(),
    ELSE
        JMP PTR old_int9_handler(),

BEGIN
    old_int9_handler = _dos_getvect(9);
    old_int21_handler   _dos_getvect(0x21);
    _dos_setvect(0x21, my_int21_handler),
     dos_setvect(9, my_int9_handler),
    go_tsr ),
```

This code hooks INT 21h to find out whether someone is "in DOS." The INT 21h handler increments a flag as it enters to an INT 21h call and decrements it on the way back out. The INT 9 handler checks the using_disk_stack flag and won't pop up if the flag's non-zero. The flag therefore acts as a semaphore, serializing access to DOS.

This is the basic idea behind making DOS calls from a TSR, but there are many problems with the preceding pseudocode. For example, DOS termination functions (functions 00h, 31h, and 4Ch) do not return and therefore would need to get special treatment. Likewise, this code does not take into account DOS critical errors. Nor does it account for the fact that a PC starting up the COMMAND.COM prompt is actually parked inside INT 21h (function 0Ah), buffered keyboard input, making it seem as if one can't pop up while at the DOS prompt, which we all know is not the case. Fortunately, this code doesn't need to work properly because MS-DOS already provides both an InDOS semaphore and a critical error semaphore that the TSR can check. Instead of hooking INT 21h in an attempt to maintain the InDOS flag, you can use the one that DOS already provides. On the other hand, this technique of hooking an interrupt to maintain some flag is the essential trick to serialize access to INT 13h, the ROM BIOS disk interrupt.

This is where newly documented DOS enters the picture. Because the DOS function that returns the address of the InDOS semaphore was once undocumented and the documentation still doesn't reveal much about how to use this function, it is associated by critical error semaphore. Furthermore, DOS generates the interrupts INT 28h while inside INT 21h (function 0Ah). As we discuss later, Microsoft originally created these workaround hooks for its own TSRs such as PRINT.COM.

After Microsoft's own TSRs use these functions, it stands to reason that developers who want to create robust TSRs probably need to use them as well. It goes against common sense to assert that using undocumented features makes a program more rather than less reliable, but who said that TSR programming was supposed to make sense? The techniques for writing correct TSRs may not be a model of software engineering at its finest, and some of the undocumented functions for TSR support have the look of granted afterthoughts rather than parts of a well-thought-out interface, but you need them if you want your program to survive in the PC marketplace.

If you're writing a TSR, you have probably already bought into most of compatibility problems, and I'd say using undocumented DOS is the least of them. The cases where I've heard people say "my TSR crashes" is not because of undocumented DOS but because of keyboard hooks. Other problems associated with popping up over screens in graphics mode, memory usage, interrupts, and the like, are located in DOS's vast uncharted areas. TSR programming, as I've said, is part art, confirmed by the fact that Microsoft finally documented a number of the TSR necessary functions that were previously undocumented.

MS-DOS TSRs

How did PC programmers find out about the undocumented TSR functions? From examining Microsoft's own TSRs, of course.

TSRs have been a part of MS-DOS since its second release in 1981. Al Steven Dake writes in his June article "Static Memory Resident Programming," *The Waite Group's MS-DOS Papers*, 1988, that TSRs were "not available within the 64K confines of the early CP/M operating system programs like Smartkey, Cuteword, and Cuspell. The early TSR programs to ship with DOS 2.x was MODE.COM, PRINT, GRAPHICS, and ASSIGN were added in DOS 2.x.

PRINT was one DOS utility program that preempts execution tasks. You can run an application at the same time that PRINT is printing a file. Only one of the two programs is running at any given instant, but the illusion of simultaneous operations is maintained by switching between them at each timer tick.

When the PRINT program is installed, it chains into the InDOS timer tick interrupt, INT 1Ch, the DOS keyboard busy loop interrupt, INT 28h, and numerous other interrupts. Hooking a large number of interrupts is unusual for a TSR. INT 1Ch and INT 28h allow the PRINT program to gain control at regular intervals independent of the user and to perform its processing operations, read, print, and close. These intervals are subtle enough so that you can't see the program appears to be operating at the same time as the PRINT program.

Every time PRINT wakes up it saves the current DTA, PSP, and the vectors for INT 1Bh (Ctrl-Break), 23h (Ctrl-C), and 24h (Critical Error). PRINT sets up its own values for these items. On exit, or before its current processing, PRINT restores these values to their original state. The TSRs presented in this chapter follow a similar structure. The miniature TSR at the end of this chapter is an enhancement of the PRINT utility. It periodically looks for files that appear in a certain subdirectory and automatically submits them to PRINT.

One of the significant improvements in MS-DOS 2.0 was the availability of a hard disk. However, this new disk usually drive C—did cause some problems with software that was hard-coded to use drive A or B. The ASSIGN utility allowed drive letters to be mapped to other drive letters. When programs asked to read drive A, they could be transparently made to access drive C instead. ASSIGN screens three MS-DOS interrupts: INT 21h, DOS Function Call; INT 25h, Absolute Sector Reads; and INT 26h, Absolute Sector Writes. When INT 25h or 26h is called and the AL register references the ASSIGNed drive, the value in AL is replaced by the new drive number. Simple, huh?

MODE is another example of a TSR that cosmetically outputs to a device. Many programs do not support serial printers (COM1, for example). MODE can, among other capabilities, redirect printer output to the serial port. The techniques employed by MODE could be used to write translator programs for various output devices. A TSR program I wrote for the nefarious ones' wife was for a printer that did not support the form feed command. The TSR would intercept the parallel printer output interrupt and check for a form feed character. When one was seen, the TSR would output the appropriate number of line feeds to get to the next page. It was a simple program, but it saved someone from having to buy a new printer.

The Generic TSR

Now it's time for some code! Our goal is to build a generic TSR with Microsoft or Borland C/C++. This chapter provides everything we need when a user-defined hotkey is pressed: a function named `application()` is called. We simply provide the application. Link with the generic TSR object modules, and you have a TSR. We've used Unreal Mode to escape from some unwieldy screen modes or even screen-savers, and restored video modes without knowing undocumented DOS. The generic TSR code deals with the issues connected with undocumented or otherwise undocumented DOS. The resulting TSRs have been tested extensively and work quite well. There are no 100% guarantees in the world of TSRs, however.

We've used the generic TSR to build three sample pop-ups: a keystroke browser (TSRHEX), a memory resident version of the MCB walker from Chapter 7 (TSRMEM), and a memory resident version of the INT 21h command interpreter that we will meet in Chapter 20 (TSR2E). We also build MTASK, the cooperative multitasking program mentioned earlier. The TSRs can be built either using the traditional DOS functions for TSRs or by using the DOSSWAP technique described later on. Unfortunately, there's no way to tell whether a given TSR uses the disk or not. To show you all these pieces put together, we make the source code available. A typical approach is first shown in the MAKEFILE for this project. Shown is listing 9-1, the file works with NMAKE from Microsoft C 6.0. Make files for Borland C++ are also supplied on the diskette.

Listing 9-1: MAKEFILE for the generic TSR

```
# NMAKE makefile for generic TSR
# example  C:\UNDOC2\CHAP9>nmake tsrfile.exe

# can be overridden from environment with NMAKE /E
# example,
#    C:\UNDOC2\CHAP9>set swap=1
#    C:\UNDOC2\CHAP9>nmake /e tsrfile.exe
#
```

```
#   C:\UNDOC2\CHAP9>set no_disk=1
#   C:\UNDOC2\CHAP9>nmake /e tsrmem.exe
SWAP = 0
NO_DISK = 0

!IF $(SWAP)
DOSSWAP = -DDOS_SWAP
!ELSE
DOSSWAP =
!ENDIF

!IF $(NO_DISK)
USES_DISK =
!ELSE
USES_DISK = -DUSES_DISK
!ENDIF

# defines the key components of the generic TSR
#   TSREXAMP.C - main
#   INDOS.C - InDOS, critical error flag
#   PSP.C - Set PSP, Get PSP
#   EXTERR.C - Extended error save and restore
#   TSRUTIL.ASM - Miscellaneous routines
#   STACK.ASM - Stack save and restore
#   DOSSWAP.C - Optional use of DOS Swappable Data
#   SWITCHER.C - Task switcher, instance data
#   NOTIFY.ASM - Task switcher notification handlers
#   BREAK.C - Ctrl-C handling

UNDOC_OBJS = indos.obj psp.obj exterr.obj break.obj switcher.obj

MULTI_OBJS = indos.obj psp.obj exterr.obj break.obj

TSR_OBJS = tsrexamp.obj $(UNDOC_OBJS) \
    tsrutil.obj stack.obj notify.obj

STSR_OBJS = tsrexamp.obj $(UNDOC_OBJS) dosswap.obj \
    tsrutil.obj stack.obj notify.obj

# command to turn a .C file into an .OBJ file
.c.obj:
    cl -AS -Ox -Zp -c -W3 -Zi -DTSR $(USES_DISK) $(DOSSWAP) $*.c

# command to turn an .ASM file into an .OBJ file
.asm.obj:
    masm -ml $*.asm;

# special handling for MULTUTIL.ASM
multutil.obj:  tsrutil.asm
    masm -ml -DMULTI tsrutil,multutil;

multstk.obj:  stack.asm
    masm -ml -DMULTI stack,multstk;

# make the file-browser sample TSR
tsrfile.exe:  $(TSR_OBJS) file.obj
    link /far/noi/map @tsrfile.rsp

# make the MCB-walker sample TSR
tsrmem.exe,  $(TSR_OBJS) mem.obj put.obj
    link /far/noi @tsrmem.rsp

# make the INT 2Fh command interpreter sample TSR

INT2F_OBJS   test2f.obj send2f.obj have2f.obj do2f.obj

INT2F = test2f.obj send2f.obj have2f.obj do2f.obj

tsr2f.exe  $(TSR_OBJS) $(INT2F_OBJS) put.obj
    link /far/noi @tsr2f.rsp

# link the dos swapple examples only if the env var set
!IF $(SWAP)

# make the file-browser sample TSR
stsrfile.exe:  $(STSR_OBJS) file.obj
```

```
    link /far/noi @stsrfile.rsp
# make the MCB-walker sample TSR
stsrmem.exe:  $(STSR_OBJS) mem2.obj put.obj
    link /far/noi @stsrmem.rsp
# make the INT 2Eh command-interpreter sample TSR
stsr2e.exe  $(STSR_OBJS) $(INT2E_OBJS) put.obj
    link /far/noi @stsr2e.rsp
!ENDIF
# make the non-pop-up PRINT add-on
multi.exe  multi.obj $(MULTI_OBJS) multutil.obj multstk.obj put.obj
    link /far noi/map/li multi $(MULTI_OBJS) multutil multstk,multi,
```

TSR Programming in Microsoft and Borland C/C++

Before beginning our examination of the various components of the generic TSR, we need to discuss writing TSRs in Microsoft and Borland C++ rather than in assembly language. This discussion strays very far from the topic of undocumented DOS information, but that's unavoidable. As a consequence, we'll cover all sorts of interesting aspects of low-level PC programming in C.

Managing TSRs is essentially a language-independent exercise, at least because you have total control of the CPU. The process becomes a lot more difficult when the actual TSR application goes beyond the scope of simple assembly-language code. C is generally easier to code than assembly language, and wealth of libraries is available. By using C to write a TSR, you give up a little efficiency but gain ease of use and manageability.

Most TSRs, even those that must be accessed through some type of interrupt. Therefore, anyone interested in TSR programming in a high-level language like C must become familiar with the facilities for interrupt manipulation.

Most C compilers for the PC offer some interrupt or interrupt keyword that helps create interrupt handlers and other TSRs. The interrupt keyword causes the compiler to create special entry and exit code for the procedure whose definition includes the interrupt modifier. On entry, the function saves all the registers and sets DS to point to the C program. Because these registers are defined as parameters and accessed on the stack, writing get and set them just like any other variable. When the procedure exits, it pops the registers values from the stack. Listing 9-2 shows example code for a simple interrupt handler.

Listing 9-2: An interrupt handler in C

```
typedef struct {
#ifdef TURBOC
    unsigned bp, di, si, ds, es, dx, cx, bx, ax;
#else
    unsigned es, ds;
    unsigned di, si, bp, sp, bx, dx, cx, ax;    /* PUSHA */
#endif
    unsigned ip, cs, flags;
    } INTERRUPT_REGS;

void interrupt far my_handler(INTERRUPT_REGS r)
{
    unsigned i = r.ax;
    r.bx = i >> 8;
}
```

Simple code for the interrupt keyword often shows an enormous parameter list for each interrupt variable with each register named separately. Using the INTERRUPT REGS structure (not a pointer to one) makes the parameter list more manageable.

What sort of code does this produce? By compiling with the Microsoft C -Fa or -Fc command line switches, you can examine the resulting assembly language code. Listing 9-3 shows the code generated

by the compilation of this interrupt procedure in Microsoft C. The order in which registers are pushed is dictated in part by the Intel PUSHA and POPA instructions. Borland C++ also offers an interrupt keyword, but the order in which it pushes and pops registers is different from and incompatible with the PUSHA/POPA instructions.

Listing 9-3: Assembly Language Generated from Listing 9-2 by Microsoft C

```
_my_handler PROC FAR
    push    ax              ; bp+18
    push    cx              ; bp+16
    push    dx              ; bp+14
    push    bx              ; bp+12
    push    sp              ; bp+10
    push    bp              ; bp+8
    push    si              ; bp+6
    push    di              ; bp+4
    push    ds              ; bp+2
    push    es              ; bp+0
    mov bp,sp
    sub sp,2
    mov ax,DGROUP
    mov ds,ax
    ASSUME DS DGROUP
    cld
    mov ax,WORD PTR [bp+18] ; i = r ax
    mov as,ah
    sub ah,ah
    mov WORD PTR [bp+12],ax , r bx = i >> 8
    mov sp,bp
    pop es
    pop ds
    pop di
    pop si
    pop bp
    pop bx
    pop bx
    pop dx
    pop cx
    pop ax
    iret
_my_handler PROC FAR
```

Passing the registers on the stack allows the C function to access the register values through variables. Because these values are popped from the stack as soon the C function can change the register values. Interrupt Notice that register BX is popped twice. Once try SP was pushed at this point. If the C function was allowed to change SP (the stack pointer), the IRET instruction would probably cause the machine to crash. IRET loads the stack to return to the caller. Notice that the processor itself pushes CS:IP and the flags on the stack.

If we compile for 80286 and higher machines with the -G2 switch, the resulting code would look like Listing 9-4.

Listing 9-4: Assembly Language Generated From Listing 9-2 with -G2 switch

```
    .286
_my_handler PROC FAR
    pusha                   ; push ax,cx,dx,bx,old_sp,bp,si,di
    push ds
    push es
    mov bp,sp
    sub sp,2
    mov ax,DGROUP
    mov ds,ax
```

```
    ASSUME DS:DGROUP
    cld
    mov ax,WORD PTR [bp+18]
    mov al,ah
    sub ah,ah
    mov WORD PTR [bp+12],ax
    mov sp,bp
    pop es
    pop ds
    popa                ; pop di,si,bp; skip sp, pop bx,dx,cx,ax
    iret
my_handler ENDP
```

Do you notice the amount of code generated, even for this best case, with PUSHA/POPA, and the large amount of stack space used for our three-line interrupt handler should not go unnoticed. If you were writing only a handler in assembly language, it might look like Listing 9-5.

Listing 9-5: Interrupt Handler in Hand-Crafted Assembly Language

```
_my_handler PROC FAR
    mov bx, ax
    shr bx, 8
    iret
_my_handler ENDP
```

Every feature has a price, and here is what you pay for the convenience of writing the application in C rather than in assembly language. Remember that for each interrupt your TSR hooks, every application which generates that interrupt will end up in your TSR's interrupt handler, even if the application is not interested in the TSR's services and even if the TSR is not going to chain to the previous handler. As we saw in chapter 6, this is especially bad problem with the long INT 21h chain. Adding C-generated interrupt handlers to this chain just makes things worse.

In addition to the interrupt or interrupt keyword, C compilers for the PC generally offer a set of functions for manipulating interrupts. In Microsoft and Borland C++, the DOS.H header file provides a large set of DOS-specific functions, including those excerpted in Listing 9-6.

Listing 9-6: Excerpts from Microsoft C DOS.H

```
void (_cdecl _interrupt _far *
    _cdecl _dos_getvect(unsigned intno))();

void _cdecl _dos_setvect(unsigned intno,
    void (_cdecl _interrupt _far *new_handler)());

void _cdecl _chain_intr(void (_cdecl _interrupt _far *target)());

void _cdecl _dos_keep(unsigned retcode, unsigned memsize);
```

The functions dos_getvect and dos_setvect directly translate into calls to INT 21h functions 25h and 35h, and are usually preferable to using the more general intdosx or int86x functions. For example

```
#include <dos.h>
//
extern void interrupt far my_int21_handler(); // declare new function
void (_interrupt _far *old_int21)();          // pointer to old function

main()
{
    old_int21 =  dos_getvect(0x21);       // save old
     dos_setvect(0x21, my_int21_handler); // install new
    //
    _dos_setvect(0x21, old_int21);        // restore old
}
```

You can do more with the old int21 function pointer than just restore it when you're finished. In fact, almost all interrupt handlers and TSRs need to do something cool with the pointer to the previous handler. They need to chain to it. Microsoft and Borland provide the extremely useful _chain_intr function which is necessary when your new interrupt handler needs to do preprocessing before chaining to the old handler. For instance:

```
void (_interrupt _far *old_int21)();
void interrupt far my_int21_handler(INTERRUPT REGS r)
{
    // do some work
    _chain_intr(old_int21);
    // never reached!
}
main()
{
    old_int21 = _dos_getvect(0x21);          // save old
    _dos_setvect(0x21, my_int21_handler);    // install new
    //
}
```

It's called interrupt chaining because each interrupt handler is akin to a link on a chain. Each one is a unit, but the units are linked together. The _chain_intr function is basically a JMP instruction. Control is passed from the current interrupt handler to the one passed as a parameter to _chain_intr. When the final interrupt handler is reached, there could be many handlers linked together. The handler performs an interrupt return, passing control back to the background application that was active when the interrupt occurred.

If you need to do more work after chaining to the old handler, called post-processing, then you can't use _chain_intr. Instead you must directly call through the saved function pointer:

```
// maybe do some preprocessing
(*old_int21)();
// we're back  do postprocessing
```

The C compiler converts the call through the interrupt function pointer into the following:

```
pushf
call dword ptr old_int21
```

The problem with this however is that the compiler uses the CPU registers in ways that may not be obvious from an examination of your C code. The registers on entry to the old interrupt handler may therefore not be correct. This is not a problem with _chain_intr because that function which can only be correctly called from within an interrupt function sets up the CPU registers with the image of the registers that were stored on the stack. Whenever possible use _chain_intr to call, rather than (*old)().

There are various tradeoffs involved in writing interrupt handlers in C rather than Assembly language. At first it seems like a win, but the overhead of pushing all registers on the stack on entry to an interrupt handler and the inconvenience of not knowing the exact state of the registers before chaining to the previous handler are sometimes too much. For instance, int 1Ch is less convenient to use than a hardware interrupt which is why I switched to Assembly language. The generic TSR uses two assembly language modules: ISRC_HI.ASM and STACK.ASM because that made more sense than a few arbitrary C code principles.

Keeping a C Program Resident

The hardest thing to do from a TSR in C is estimate the amount of memory you want to keep resident. Both Microsoft and Borland provide a handy dos_keep function (described in DOSH) see the excerpts in Listing 9-6) which calls the DOS TSR function. But you still have to estimate the

question of what number to pass as memsize to _dos_keep. When coding in assembly language, you can come up with this number fairly easily because you can find the size of your code. You have to use the ORG directive or an equivalent allowing you to perform such efficiencies as placing startup code at the end and jettisoning it when your program resides. You can define addresses at the end of each segment and use the address to calculate the size of the segment. You can then total the size used in each segment to obtain the size required.

If you do not control the memory structure of the program beyond your source code. The memory map for a small model Microsoft C program with hypothetical segment addresses is shown in Figure 9-7.

Figure 9-7: Memory Map of a Small Model Microsoft C Program

```
          ---------------
1E20h     FAR HEAP
          ---------------
          NEAR HEAP
          STACK
0E19h     DS
          ---------------
0BFAh     CODE
          ---------------
0BEAh     PSP
          ---------------
```

For Borland C++, the STACK and NEAR HEAP are reversed. Several readers did not agree with this memory map, but it can be validated by running a C program in a debugger. If a break point is set in the main function, you can look at the value of the SP register. For Microsoft C, SP is a low address. For Borland C++, SP is a high address beyond the stack segment.

Of course, you could just pass a very high number to _dos_keep, but with TSRs one of the primary goals is to keep memory consumption to the absolute minimum. The code fragment in Listing 9-8 details one way to keep the near segment resident in C for small memory models.

Listing 9-8: Sample Code for Keeping Memory Segment Resident

```
#define PSP_ENV_ADDR    0x2c  /* environment address from PSP */
#define STACK_SIZE      8192  /* must be 16 byte boundary */

#define PARAGRAPHS(x)   (((FP_OFF(x) + 15) >> 4)

char far *stack_ptr;          /* pointer to TSR stack */
unsigned memtop,              /* number of paragraphs to keep */

//
/* MALLOC a stack for our TSR section */
stack_ptr = malloc(STACK_SIZE);
stack_ptr += STACK_SIZE;
//
/* release environment back to MS-DOS */
FP_SEG(fp)  = _psp;
FP_OFF(fp) = PSP_ENV_ADDR;
_dos_freemem(*fp);
/* release unused heap to MS-DOS */
/* All mallocs for TSR section must be done in TSR init */
segread(&sregs);
memtop  = sregs.ds + PARAGRAPHS(stack_ptr) - _psp;
_dos_setblock(memtop, _psp, &dummy);
_dos_keep(0, memtop);
```

First create a block of memory on the near heap as you normally do. This becomes the TSR's stack during activation. The alternative to using this local stack is to use whatever stack happens to be in

effect during TSR activation. This is fine for small programs, but if you are doing wild and wonderful things with your code, it is best to create your own stack to avoid overflowing the foreground's stack. The stack size is added to the stack pointer variable to get it to the bottom of the stack. This stack bottom becomes the top of the TSR in memory.

Use the value of the new stack pointer to calculate the number of 16-byte paragraphs that must be kept resident in memory. The expression PARAGRAPHS stack_pointer is used to find the number of paragraphs in the local heap. This number must be returned because it includes the stack you've already done. This is added to DS to establish the top of the memory your local and the SP is subtracted to find the actual number of paragraphs needed by the entire program. Call MS DOS to shrink the current block down to the size specified. In simple programs created with this general TSR, memtop was generally less than 0400h paragraphs, giving the resulting TSR an 8K memory footprint of about 24K. This eliminates any far heap the original C stack and the entire near heap.

Using this method, you must perform any near mallocs before creating the stack. Once the TSR is resident, you cannot call the malloc family of functions from routines that use malloc functions because the near heap is gone. Use of malloc calls by library functions varies with the compiler you're using, so be sure to select your functions carefully. The *Run-Time Library Reference* for Microsoft C 6.0 includes in the entry for malloc a list of all functions that call malloc. It's rather large. The final step is to call _dos_keep, which does an INT 21h function 31h to terminate and stay resident, retaining in memory the number of paragraphs specified. If all goes well, you should be able to find your TSR in the display from Chapter 7's UMEM program. For example:

```
C:\UNDOC2\CHAP9>tsrfile -k 59 4
Activation: CTRL SCAN=59
C:\UNDOC2\CHAP9>umem
Seg     Owner   Size
...
08DA    1E76    0009 (   208)
08E8    0000    0000 (     0)   free
08E9    08EA    0597 ( 22896)          -k 59 4  [08 09 13 28 2F ]
```

The MEM display shows that the TSR begins at 08E9. Its MCB is at 08E8, that it retains 0597h paragraphs (22K), and that we used the command line which, by the way, designates a hotkey of Ctrl-Esc. But the program name is strange, isn't it? As for the various interrupts, UMEM says you've hooked 13, 28, and 2F, as discussed a bit earlier.

One final note about staying resident: Some C programs do not release their memory, despite having even further-many TSRs jettison their startup code. For example, you'd expect that once your program goes resident, any subsequent calls to TSRFILE would fail, for instance, by going to get the memory and getting a different instance of the program, not the one that's resident. Copying. There is one program, but possibly more than one process. You know at which point you can throw away the code or data. This is a technique that is relatively easy using assembly language. Figuring out how to do it in C, given the memory map shown earlier, is left as an exercise for the reader. Don't stay up too late!

Not Going Resident

If you are writing your own TSR from scratch, rather than using one of the commercial TSR libraries, or a generic TSR such as the one we present here, it is a good idea to put off going resident for as long as possible. Don't even consider plugging your application as a TSR. Instead, have it spawn a command shell from which you can exit, or have it run a single program whose name and arguments appear on the DOS command line, as shown in Listing 9-9.

Listing 9-9: Sample Code for Shell vs. TSR Implementation

```
main(int argc, char *argv[])
{
    // TSR init goes here
    old_int09 = _dos_getvect(0x09);
     dos_setvect(0x09, my_int09_handler);

#ifdef TESTING
    // to launch a command shell
    system(getenv("COMSPEC"));

    // or, to run just one program:
    // spawnvp(P_WAIT, argv[1], &argv[1]);

    // we're back, deinstall
    _dos_setvect(0x09, old_int09);
#else
    //
    _dos_keep(0, _memtop);
#endif
}
```

Later, to be more friendly, we might consider making some of our applications into shells rather than TSRs. A program that needs to set up a context of some sort for another program is often best treated as a shell rather than a TSR. See the two application wrapper examples at the end of Chapter 2 (DOSWRAP and FUNCOF32).

Jiggling the Stack

Remember, a TSR's stack was created with a malloc just before terminating resident. For that stack to be used, the ISR interrupt routine that performs activation must take two entries: one sets up the local stack on entry and one restores the original stack on exit. The actual code to switch stacks must be programmed in assembler, as high-level languages don't have full access to the registers (C, though, you could use in-line assembler, as discussed in the reference section functions of PHARLAP OMF, in Chapter 8).

Listing 9-10 is a small assembly language module that manages the stack context switch. The set_stack procedure saves the current foreground stack in the data area and sets the stack pointer to the stack created with malloc (stack_ptr). Notice the stack manipulation at entry and exit of this procedure. A return address was placed on the stack when set_stack was called. Because this code switches stacks, this address is popped from the stack on entry and pushed on the stack before exit. The restore_stack procedure restores the stack segment and pointer to what was saved by set_stack.

Listing 9-10: Stack Switch Module STACK.ASM

```
;STACK.ASM
;Define segment names used by C
;
_TEXT   segment byte public 'CODE'
_TEXT   ends
CONST   segment word public 'CONST'
CONST   ends
_BSS    segment word public 'BSS'
_BSS    ends
_DATA   segment word public 'DATA'
_DATA   ends
DGROUP  GROUP   CONST, _BSS, _DATA
    assume  CS:_TEXT, DS:DGROUP
    public  _set_stack, _restore_stack
```

```
    extrn   _stack_ptr:near     ;our TSR stack
    extrn    ss_save:near       ;save foreground SS
    extrn   _sp_save:near       ,save foreground SP

_TEXT   segment
;*****
;void far set_stack(void) -
;   save current stack and setup our local stack
;*****
_set_stack  proc    far

;save foreground stack

;we need to get the return values from the stack
;since the current stack will change
    pop ax  ;get return offset
    pop bx  ;get return segment

;save away foreground process' stack
    mov word ptr _ss_save,ss
    mov word ptr _sp_save,sp

;setup our local stack
    mov ss,word ptr _stack_ptr+2
    mov sp,word ptr _stack_ptr

IFDEF MULTI
   mov bp,sp   ;make bp relative to our stack frame
ENDIF
;setup for ret
    push    bx
    push    ax

    ret
_set_stack  endp
;*****
;void far restore_stack(void) -
;   restore foreground stack, throw ours away
;*****
_restore_stack  proc    far

;we need to get the return values from the stack
;since the current stack will change
    pop cx  ;get return offset
    pop bx  ;get return segment

;save background stack
    mov word ptr _stack_ptr+2,ss
    mov word ptr _stack_ptr,sp

;restore foreground stack here
    mov ss,word ptr _ss_save
    mov sp,word ptr _sp_save

IFDEF MULTI
   mov bp,sp   ,make bp relative to our stack frame
ENDIF

;setup for ret
    push bx
    push cx

    ret
_restore_stack  endp
_TEXT   ends

_DATA   segment

_DATA   ends

    end
```

...) ...and can call DOS if the stack is valid. ...cial to compile Microsoft C with -Gs (or with a switch ...) ...DOS that includes -Gs as the default stack checking. Otherwise, the C compiler's chkstk routine would get hopelessly confused by the new stack.

DOS Functions for TSRs

...Let's now turn our attention to discussing TSR programming with DOS functions. Recall that the whole issue is ...how much it uses DOS INT 21h calls from the resident portion of a TSR. First we present the tradi... ...solutions, which are completely undocumented DOS. Then we show the undocumented DOSSWAP tech... ...niques.

MS DOS Flags

...DOS keeps ...which is nonzero only if the InDOS flag, also known as the "DOS safe" flag. This flag ...indicates whether it is safe to access MS DOS functions. It is a semaphore that turns DOS into a serially ...reusable resource. Every chapter 6 shows where DOS ...increments and decrements the ...InDOS flag. ...decrement DOS ...is critical error DOS that is made INT 21h calls. If the semaphore ...decrement DOS ...Yes. As we'll see, there are various exceptions to this rule, but the basic idea ...is sound.

...Consider ...the ...situation ...of a TSR that uses MS DOS checks this flag. If the flag indicates ...that MS DOS ...busy, the TSR program must defer the activation of at least that portion of the acti... ...vation ...that ...makes INT 21h calls. DOS INT 21h Function 34h returns the address of the InDOS ...flag. ...Because ...DOS ...increases ...reasons ...that ...DOS ...is constant for a particular operating environment, the ...usual ...approach ...for ...TSR ...calls ...DOS ...to ...obtain ...once. You can then store the address in a local vari... ...able ...for ...later ...access ...in ...the ...pop-up ...process.

...The C ...module ...NODOSC.C ...in ...Listing ...9-11 ...contains ...a ...function ...DosBusy ...that returns a zero if it is safe to make INT 21h calls. If DOS cannot be interrupted, it returns non-zero. Your application must call InitInDos to set the address of the InDos flags during initialization. If you neglect to do so, DosBusy always returns non-zero. Of course, DosBusy could instead just call InitInDos for you at this point.)

...The ...Int28DosBusy ...function ...in ...Listing ...9-12 ...returns ...a ...zero ...if ...the ...InDos ...flag ...is ...greater ...than ...one or the critical error flag is not zero, and a non-zero if DosBusy is used only inside an INT 28h loop. Inside INT 28h, InDOS -- ...is ...normal ...but ...forces ...DOS ...to ...not ...busy. ...InDOS ...= ...1 ...inside ...INT ...28h ...means ...it ...is ...busy.

Listing 9-11 DOS Flag Management Module INDOS.C

```
/* INDOS.C - Functions to manage DOS flags */

#include <stdlib.h>
#include <dos.h>

#define GET_INDOS       0x34
#define GET_CRIT_ERR    0x5D06

char far *indos_ptr = 0;
char far *crit_err_ptr = 0;
int   DosBusy(void);
void  InitInDos(void);

/*****
Function: Init InDos Pointers
Initialize pointers to InDos flags
*****/
void InitInDos(void)
{
    union  REGS regs;
    struct SREGS segregs;
```

```
    regs.h.ah = GET_INDOS;
    intdosx(&regs,&regs,&segregs);
    /* pointer to flag is returned in ES:BX */
    FP_SEG(indos_ptr) = segregs.es;
    FP_OFF(indos_ptr) = regs.x.bx;
    if ( osmajor < 3)  /* flag is one byte after InDos */
        crit_err_ptr = indos_ptr + 1;
    else if (_osmajor==3 && _osminor == 0) /* flag is 1 byte before*/
        crit_err_ptr = indos_ptr - 1;
    else
    {
        regs.x.ax = GET_CRIT_ERR;
         intdosx(&regs,&regs,&segregs);
        /* pointer to flag is returned in DS:SI */
        FP_SEG(crit_err_ptr) = segregs.ds;
        FP_OFF(crit_err_ptr) = regs.x.si;
    }
}
/*****
Function  DosBusy
This function will non-zero if DOS is busy
*****/
int DosBusy(void)
{
    if (indos_ptr && crit_err_ptr)
        return (*crit_err_ptr || *indos_ptr);
    else
        return 0xFFFF;  /* return dos busy if pointers are not set */
}
/*****
Function: Int28DosBusy
*****/
int Int28DosBusy(void)
{
    if (indos_ptr && crit_err_ptr)
      return (*crit_err_ptr || (*indos_ptr > 1));
    else
      return 0xFFFF;  /* return dos busy if flags are not set */
}
```

Listing 9-1 puts the cart before the horse by referencing another byte in addition to the InDOS flag. This is the Critical Error flag. The DOS Critical Error flag is set when DOS is processing a critical error. As a result, it is not another flag that must be checked before deciding that it is safe to access MS-DOS. In MS-DOS version 2.x, this flag is one byte after the InDOS flag. In MS-DOS version 3.x and higher, this flag is one byte before the InDOS flag. When interpreting these flags, you must check the DOS version. In MS-DOS versions 3.10 and above, you can use a return from the undocumented Get List of Lists function (INT 21h, function 52h). All the DOS version-to-version problems are taken care of during initialization in InitInDos, so that DosBusy, which is called quite frequently, has an easy job.

In addition to checking if DOS is in the middle of a critical error, another use for the critical error flag is to force MS-DOS to use its critical error stack. A bug in MS-DOS 3.x requires that the critical error flag be set, and therefore DOS's critical error stack be used, so that the Get DSP and Set DSP functions, discussed momentarily, work properly. You can avoid having to worry about the problem by requiring DOS 3 or higher.

As yet another forward reference, note that INDOS.C also provides a function called Int28DosBusy() to be used with an INT 28h handler. Inside INT 28h, InDOS is always at least one. In this context, InDOS > 1 means DOS isn't busy; this is one of the many InDOS exceptions we were talking about. In total, InDOS > 1 when DOS is really busy, some background task is executing.

Get/Set PSP

As discussed in Chapter 6, particularly in the section "Unique Process Identifier," each process in MS-DOS has a Program Segment Prefix. You learned that Memory Control Blocks are stamped with the PSP of their owner. In Chapter 7, you saw that this 2-byte field is used, among other things, to construct file handle tables. Job File Tables for the process. Because it is a unique value, though, as chapters 3 and 6 note, this can get complicated in 386-and-better multitasking environments; the segment address of the PSP also acts as a unique process identifier.

At any given moment in an MS-DOS system, there is a current PSP. In the appendix entry for INT 21h, I note that DOS 5.0/6.0 and 3.0/3.3 store this segment at offset 10h in both versions of the DOS Swappable Data Area. When DOS receives an INT 21h Function 3Bh request to open a file, for example, the handle returned to the AX register is entered into the JFT of the current PSP.

Well, I said previously the PSP that belongs to whatever process is in. INT 21h Function 3Dh, right? Not! Remember that we are talking about TSRs here. The current PSP, unless you somehow change it, belongs to whatever process appears to be running when you pop up. Thus, if the TSR decides to start opening files, it would be using the foreground process's PSP. This could be totally disastrous.

Consider the following example of a TSR that ignores the current PSP when it pops up. If the TSR opens a file handle or allocates memory using MS-DOS, these resources become associated with the foreground process. The foreground process is not aware of these new JFT entries as its JFT are consumed. When the foreground terminates, all open files are closed and allocated memory segments are freed. This results those which the TSR thought it was going to be allowed to be associated with the foreground process. Furthermore, if the TSR opens a file when popped up, it sets one PSP and tries to read from the file while popped up, set a shift to a SFT that is not the one it was reference the wrong file!

What the TSR must do when it pops up is somehow change DOS's current PSP so that it corresponds to the TSR's, carry out whatever task the TSR is supposed to perform when it pops up, and then, before lapsing back into its dormant state, restore the current PSP to whatever value it had when the TSR popped up.

Fortunately, DOS provides just the functions you need. DOS INT 21h Functions 50h and 51h are the Get PSP and Set PSP functions in MS-DOS 2.x. In DOS 3.x and above, documented Function 62h is also available for Get PSP. As you've seen, I've often thought that Get PSP returns the PSP of whatever program called it. As you've seen, however, it gets DOS's current PSP, not of the XDA Processor. Set PSP sets the current PSP.

In DOS 3.0 and higher, Functions 50h, 51h, and 62h also set and get the DOS stacks and are fully reentrant. They are among the few INT 21h functions that can be called without paying attention to the InDOS flag, and they don't use or construct and use their own stacks. But, as noted earlier, to call Functions 50h or 51h in DOS 2.x, you must first set the critical error stack. The following pseudocode describes the steps to execute a Set PSP call in a TSR:

```
TSR_INITIALIZATION:

     psp_addr =
     Get current PSP with Function 51h or 62h
     (this PSP will be that of the TSR)
     .
     Terminate and stay resident
TSR_ACTIVATION:
     fgrnd_psp_addr =
     Get current PSP with Function 51h or 62h
     (since the TSR interrupted the foreground, this address
        will be that of the foreground process)
     Set current PSP with Function 50h, using psp_addr
     Do TSR work
```

```
    Set current PSP with Function 50h, using fgrnd_psp_addr
    Go back to sleep
```

Listing 9-12 PSP.C contains functions that Get and Set the current PSP, taking into account the various oddities which we have discussed. These are not just simple-minded sugar coating for the equivalent DOS functions. We test for DOS 2.x and set the critical error flag accordingly. Again, you must call InitInDos before using these functions.

Listing 9-12: PSP Management Module PSP.C

```
/* PSP.C */

#include <stdlib.h>
#include <dos.h>
#include "tsr.h"

#define GET_PSP_DOS2    0x51
#define GET_PSP_DOS3    0x62
#define SET_PSP         0x50

extern union  REGS regs;

/*****
Function: GetPSP - returns current PSP
*****/
unsigned GetPSP(void)
{
    if (_osmajor == 2)
    {
        if (! crit_err_ptr) /* forgot to call InitInDos */
            return 0,  /* gosh, I should just call InitInDos for them */

        *crit_err_ptr = 0xFF,   /* force use of proper stack */
        regs.h.ah = GET_PSP_DOS2,
        intdos(&regs,&regs),
        *crit_err_ptr = 0,
    }
    else
    {
        regs.h.ah = GET_PSP_DOS3,
        intdos(&regs,&regs),
    }

    return regs.x.bx;
}

/*****
Function  SetPSP - sets current PSP
*****/
void SetPSP(unsigned segPSP)
{
    if (!crit_err_ptr)          /* forgot to call InitInDos */
        return;          /* should call InitInDOS for them! */

     if (_osmajor == 2)
        *crit_err_ptr = 0xFF;  /* force use of correct stack if DOS 2.x */

    regs.h.ah   SET_PSP,
    regs.x.bx   segPSP,         /* pass segment value to set */

    intdos(&regs,&regs);

     if (_osmajor == 2)
        *crit_err_ptr = 0,      /* restore crit error flag */
}
```

Extended Error Information

Consider the following scenario. The foreground program has performed a DOS function that failed. Because of this, DOS has stored extended error information. Normally, the foreground

program can access the extended information at this point. The TSR becoming active, however, delays the access of the extended error information. Now the TSR has control and could possibly perform DOS functions that fail, overwriting the existing extended error information, making it invalid for the interrupted (foreground) program.

Don't despair though. DOS has this problem well in hand. In DOS 3.0 and higher, documented Function 59h is available to query the extended error information. A TSR must save this information prior to activation and restore it at exit. DOS Function 5D0Ah allows the extended error information to be set. On entry to Function 5D0Ah, point DS:DX to (not DS:SI as claimed in the *MS DOS Programmer's Reference*) for DOS 5) to a table containing the contents of the registers when an error occurred. The register values for this table can be retrieved using Function 59h.

The C functions in Listing 9.13 can get the extended error information on TSR activation and reset the extended error information on exit.

Listing 9.13. Extended Error Management Module EXTERR.C

```
/* EXTERR.C - extended error saving and restoring */

#include <stdio.h>
#include <dos.h>

#define GET_EXTERR      0x59
#define SET_EXTERR      0x5d0a

#pragma pack(1)

struct  ExtErr
{
   unsigned int errax, errbx, errcx, errdx, errsi, errdi,
   unsigned int errds, erres,
   unsigned int reserved, userID, programID,
};

void  GetExtErr(struct ExtErr * ErrInfo);
void  SetExtErr(struct ExtErr near * ErrInfo);

extern union  REGS regs;
extern struct SREGS sregs;


/*****
Function: GetExtErr
get extended error information
*****/
void GetExtErr(struct ExtErr * ErrInfo)
{
   if (_osmajor >= 3)   /* only for DOS 3 and above */
   {
      regs.h.ah = GET_EXTERR;
      regs.x.bx = 0;  /* must be zero */
      intdosx(&regs,&regs,&sregs);
      ErrInfo->errax = regs.x.ax;
      ErrInfo->errbx = regs.x.bx;
      ErrInfo->errcx = regs.x.cx;
      ErrInfo->errdx   regs.x.dx;
      ErrInfo->errsi = regs.x.si;
      ErrInfo->errdi = regs.x.di;
      ErrInfo->errds = sregs.ds;
      ErrInfo->erres = sregs.es;
      ErrInfo->userID = 0;      /* zero per DOS 5 Tech Ref */
      ErrInfo->programID = 0;
   }
}
/*****
Function  SetExtErr
```

```
set extended error information
*****/
void SetExtErr(struct ExtErr near * ErrInfo)
{
   if (_osmajor >= 3)   /* only for DOS  3 and above */
   {
      regs.x.ax = SET_EXTERR,
      regs.x.bx = 0;       /* must be zero */
      segread(&sregs),   /* put address of err info in DS:DX */
      regs.x.dx = (int) ErrInfo,
      intdosx(&regs,&regs,&regs);
   }
}
```

Extended Break Information

At times it's necessary to tell the operating system "Hey, stop what you're doing and go back to the command prompt." This is better known as Ctrl-C or Ctrl-Break.

MS-DOS by default checks the incoming keys for these break characters only when you use the CP/M-emulation I/O functions (INT 21h AH=01h through 06h). If BREAK=ON, however, DOS checks for the break key when processing almost all INT 21h functions. See the INT 21h dispatch discussion in Chapter 6. While at the COMMAND prompt entering BREAK=ON also sets extended break checking, and BREAK=OFF turns off the extra checks.

Now, what does this have to do with a TSR?

If extended break checking is on, and you press a break key just before the TSR becomes active, an MS-DOS internal flag in the TSR is lit. This is a small window of disaster, but it could happen just as you're ready to save that large program you've been editing.

To avoid this possibility, your install routine should query and save the current break status. Then, the first DOS function call within the TSR activation section must be to turn extended break checking off. On TSR exit, restore the original break status.

The only problem with this solution concerns DOS 2.x, where getting and setting the extended break status causes a fatal error if a break key is pending, and extended break checking is ON. This is corrected in DOS 3.0 and later. I don't know of any clean solution for DOS 2.x. To avoid problems with the TSR examples in this chapter, extended break checking must be OFF for DOS 2.x.

Listing 9-14 shows BREAK.C, containing C functions to get and set the extended break status.

Listing 9-14: Extended Break Management Module BREAK.C

```
/* BREAK.C */

#include <stdlib.h>
#include <dos.h>
#include  tsr.h

#define GET_SET_BREAK  0x33
#define GET_BREAK 0
#define SET_BREAK 1

extern union  REGS regs;

/*****
Function: GetBreak - returns current Break Status 0 = OFF, 1 = ON
*****/
int GetBreak(void)
{
     if (_osmajor != 2)
     {
        regs.h.ah = GET_SET_BREAK;
        regs.h.al = GET_BREAK;
```

```
        intdos(&regs,&regs);
        return regs.h.dl;
     }
     else
        return (0);
}
/*****
Function  SetBreak   sets current Break Status 0 = OFF, 1 = ON
*****/
void SetBreak(int breakStatus)
{
     if (_osmajor != 2)
     {
        regs.h.ah = GET_SET_BREAK;
        regs.h.al =  SET_BREAK;
        regs.h.dl = breakStatus;
        intdos(&regs,&regs);
     }
}
```

Interrupt 28h

The ISR can now pop up whenever DOS is not busy. So you're sitting at the COMMAND.COM prompt not doing anything, so the ISR's hotkey and the ISR doesn't pop up?

This was the answer we expected. It was. If you're not doing anything, the ISR should pop up as soon as a keypress is noticed. Sitting at the COMMAND.COM seems like the epitome of idleness. Why doesn't the ISR pop up?

The answer is quite simple. COMMAND.COM is not the first application to DOS. As will be explained in Chapter 10, whenever COMMAND.COM is finished executing a command, task, and is awaiting your next instruction, it calls the documented DOS function of keyboard input (INT 21h Function 0Ah). This function provides the standard DOS editing keys such as F3. While idling at the prompt waiting for you to type something, COMMAND.COM is parked inside INT 21h Function 0Ah. In other words, the InDOS flag is set.

Now what if you could find an alternative way to tell whether the CPU is really idle and declare that the ISR won't pop up if the COMMAND prompt is not active? You're probably not going to sell a lot of copies of the program that way, though.

This curious paradox—that InDOS flag is set when DOS is really idle—must have confronted Microsoft when it was putting together the PRINT program. Since PRINT is not a pop up, but the same principles apply. When COMMAND.COM is waiting for input, PRINT seems to be a good time for the ISR to print some files. And that's exactly what PRINT does. Now that in fact it does print in the background while COMMAND is busy. So it's not Microsoft's best hunch.

The patch is a hack so that whenever DOS is not busy—or is busy at keypress in places like Function 0Ah—it specifically generates an interrupt 28h. PRINT hooks this interrupt, checks receiving wake up, leaves the state of the InDOS flag as it was, indicates that it shouldn't. INT 28h is referred to as an MS-DOS Idle interrupt. Keep this in mind. I'll refer to it as the Idle interrupt. Whenever this Idle interrupt gets called, it's safe to issue INT 21h functions 01h–0Ch, as long as InDOS is not greater than one. INT 28h is undocumented, but it's a well-known part of TSR programming that it is supported even in the DOS compatibility box of OS/2.

The above discussion is slightly misleading because, as Chapter 10 also explains, in DOS 5 and higher COMMAND.COM first calls the DOSKEY Read Command Line function (INT 2Fh AX 4810h) and only calls INT 21h AH 0Ah if the DOSKEY function fails (probably because DOSKEY isn't installed). However, DOSKEY also issues the INT 28h ISR "heartbeat," just as DOS does while processing INT 21h AH 0Ah so INT 28h is safe whether or not DOSKEY is running. DOSKEY also uses the INT 2Fh AX 1680h call that Windows uses for idle detection.

Thus our TSR has acquired another wrinkle. In addition to checking the InDOS and critical error flags, saving and restoring DOS's current PSP, and saving and restoring the execution stack pointer, you must now also hook INT 28h. Too Well, no one ever said the DOS TSR interface was a model of clarity. It is unlikely that anyone at Microsoft sat down and tried to design the interface for TSR programming. Instead they put in what they needed to write their own TSRs. The end result is a interface that looks like someone, somewhere, would design only for their own use. On the other hand, the DOS TSR interface, if we can call it that, here is how the two Microsoft designers used it themselves. They ran into the same problems you run into with most TSRs, so they put in solutions.

Interrupt handlers for INT 28h should pass control to the previous INT 28h routine with a few exceptions. Generally they should not stop the INT 28h interrupt by executing large amounts of code. TSRs that sometimes use input should not only hook INT 28h but also periodically invoke INT 28h to check their input stack. This gives other TSRs a chance to use the idle time. Even generic TSR uses the INT 28h to detect whether the user had earlier pressed the hotkey at a time when we could not pop up. In the MULTI TSR program at the end of this chapter, INT 28h is hooked so that we can use the time slices we get while the system is sitting at the COMMAND prompt.

The INDOS.C module shown earlier contains the function called In28HookRoutine, which returns zero if it is safe to access DOS during an INT 28h. The InDOS flag is never zero during an INT 28h, so you might think that you don't need to check InDOS during an INT 28h. However, InDOS could be greater than one, in which case you still can't pop up.

The INT 28h handler appears in the main TSR module, TSREXAMP.C, to which we now turn.

Inside the Generic TSR

The main module of our generic TSR, TSREXAMP.C, initializes the program, hooks the pop up routine calls your application, and several interrupt handlers. The remainder of the interrupt handlers are written in assembly language for reasons noted earlier and are found in TSR_ISR.ASM. Naturally, TSREXAMP.C relies heavily on the variables we have already examined: INDOS.C, PSP.C, INTERRC, and STACK.ASM.

Rather than plunge directly into the 550 lines of code belonging to TSREXAMP.C, the 250 lines of code in TSRUTIL.ASM will be examined first. TSRUTIL.ASM will start off with a pseudocode explanation. The following pseudocode makes heavy use of the keyword ON, borrowed from BASIC, which I have borrowed from dBASE III. ON is a BASIC statement that is used to trap errors, or to trap user input in a program such as from outside the program flow. Here we use it to trap a hotkey entered by the user using the interrupt keyword discussed earlier in this book. Using this example, does Ctrl-8 work? Ctrl-9? Ctrl-ON keyword is used in the following pseudocode. Spend a little time experimenting with what happens in our TSR.

The first thing discussed assumes that the TSR is going to access the disk during its pop up phase, and that the TSR does not use the DOSSWAP interface, which we will mention but not yet discussed in detail.

The main function of the generic TSR looks something like this:

```
INIT ; main() in TSREXAMP.C
    IF they want to deinstall
        CALL deinstall()
    ELSE IF TSR not already installed
        MALLOC stack
        GETVECT TIMER(8), KEY(9), DISK(13h), IDLE(28h), MULTIPLEX(2Fh)
        , 2Fh  is for communication with already resident copy of TSR
        ; (install check, deinstall)
        SETVECT TIMER, KEY, DISK, IDLE, MULTIPLEX
```

```
        RELEASE environment
        RELEASE unused heap
        TSR
```

There are two purposes here, except perhaps the fact that we are somehow using INT 2Fh to communicate between an already resident copy of the TSR program and a second copy that, rather than go TSR, demasters the resident copy. If TSRFILE has already been made resident, it can be demstaled by typing TSRFILE /U at the COMMAND prompt. If you are starting rather than demstaling, then the TSR first checks to see if the TSR is already installed, also via INT 2Fh, incidentally. If it isn't installed when the INIT routine completes the program terminates but remains memory resident, and the interrupt handlers have been installed.

Before examining the interrupt handlers, let us create a few storage places that the interrupt handlers will use to communicate among themselves:

```
FLAG wanted_pop up          ; wanted to pop up earlier, but DOS was busy
FLAG disk_unsafe            ; INT 13h in use?
FLAG idle_int               ; is INT 28h in progress?
```

InDOSis not needed here because this flag is maintained by DOS even if it is not located inside the program. We use an InDosBusy() routine to check InDOS.

The first interrupt handler to examine is the one that handles keyboard events. Because we installed an INT 9 handler, each time the user presses any key, a piece of code like the following gets executed:

```
ON KEY ; new_int9() in TSREXAMP.C
    IF we are not already running AND
        IF it's our hotkey AND
            IF NOT disk_unsafe THEN
                CALL POP UP                                          ;
            ELSE
                ; we can't pop up now, so just set flag indicating that
                ; we WANT to pop up at the next available moment
                wanted_pop up = TRUE
                JMP previous KEY handler
        ELSE
            ; not our hotkey - chain to next handler
            JMP previous KEY handler
    ELSE
        ; we're already running - let key beprocessed normally
        JMP previous KEY handler
```

In the simplest scenario, the user presses the hotkey at a time when INT 13h isn't in use. Our keyboard handler then calls the POP UP routine:

```
POP UP ; tsr_function() in TSREXAMP.C
    CALL set_stack() ; switch to our own stack
    IF DosBusy() AND NOT idle_int
        wanted_pop up = TRUE
    ELSE
        ; we really can POP UP now!
        GETVECT CTRL-BREAK(1Bh), CTRL-C(23h), CRITERR(24h)
        SETVECT CTRL-BREAK, CTRL-C, CRITERR
        current_PSP = GetPSP()
        CALL SetPSP(TSR PSP) ; TSR PSP and TSR_DTA were set in init
        current_DTA = GetDTA()
        CALL SetDTA(TSR_DTA)
        save_err = GetExtErr()
        eat keys
        CALL application()
        CALL SetExtErr(save_err)
        CALL SetDTA(current_DTA)
        CALL SetPSP(current_PSP)
```

```
        SETVECT CTRL-BREAK, CTRL-C, CRITERR , REVERT
ON CTRL-BREAK DO NOTHING
ON CTRL-C DO NOTHING
ON CRITERR , new_int24() in TSREXAMP.C
    RETURN FAILURE
```

Continuing with the simplest scenario, let's say that DosBusy returns FALSE. The program then proceeds to install three short term interrupt handlers. The Ctrl-Break and Ctrl-C handlers merely discard these events. A more sophisticated TSR might do something to stay with them. The Critical Error handler merely returns failure. The key point is that the popup portion of the TSR must run its own handlers for these events, not whatever handler the foreground process happens to have installed at the time. Next the TSR swaps in your Disk Transfer Area and PSP with that of the foreground process, and saves the extended error information. Then comes the part where we check to see if the keys are barking on the keyboard buffer and finally calls the application which, as we know, does something useful for the privilege, e.g. notepad, drawing a mustache, or playing a tune from *Pinafore*. When the application finishes, the TSR puts everything back the way it found it.

That was the simplest scenario. Say the user has pressed the hotkey, but the TSR can't pop up. Either INT 13h is in use or DOS is not safe. That is, InDOS is set and DOS is not inside an INT 28h idle interrupt. In this case, either the keyboard handler or the popup routine sets the wanted_popup flag and returns immediately, in the case of the keyboard handler with an IRET.

So all the TSR has done is set the wanted_popup flag. How is this going to help the TSR pop up?

Remember the INT 8 timer tick handler the TSR installed. At each timer tick, about 18.2 times a second, unless someone has reprogrammed the chip that generates these interrupts, our TIMER routine gets woken up. Its job is to check the wanted_popup flag.

```
ON TIMER ; new_int8() in TSREXAMP.C
    CALL previous TIMER handler
    IF NOT tsr_active
        IF wanted_popup
            IF NOT DosBusy()
                IF NOT disk_unsafe
                    wanted_popup = FALSE
                    CALL POP_UP
```

Once the wanted_popup flag has been set, the TIMER routine checks 18.2 times a second to see if it's now safe to pop up. In this case, it is safe to pop up, at which time the flag is turned off.

One thing not shown in pseudocode but apparent in the genuine article in TSREXAMP.C and TSRUTIL.ASM is that for all hardware interrupts, not INT 8 or INT 9, the TSR returns to the previous handler. In addition to saving the previous interrupt handler an opportunity to do its thing, it also executes a previous handler to send the end of interrupt EOI command to the Intel 8259A interrupt controller. This is why you won't find the otherwise obligatory calls to port 0x20, 0x20 sprinkled throughout the code.

In addition to INT 8 ticks, you can also use the Idle interrupt as a trigger for servicing a wanted popup request. Note also that the IDLE handler increments and decrements the idle int flag, which is checked on entry to the INDOS() routine.

```
ON IDLE ; new_int28() in TSREXAMP.C
    INCR idle_int
    IF wanted_popup
        IF NOT Int28DosBusy()
            IF NOT tsr_active
                IF NOT disk_unsafe
                    POP_UP()
```

```
    DECR idle_int
    CALL previous IDLE handler
```

Finally, how does the important disk unsafe flag stay updated. There is unfortunately no flag in the BIOS that we can get a far pointer to as we did with InDOS, so we hook INT 13h to create our own disk unsafe semaphore.

```
ON_DISK ; new_int13() in TSRUTIL.ASM
    INCR disk_unsafe
    CALL previous DISK handler
    DECR disk_unsafe
```

That's about all there is to the generic TSR. Note how decentralized the code for a TSR is. Rather than have one top-level routine that calls various subroutines, there is instead a collection of independent handlers that get called due to some event taking place outside the program. The system has no "loop" and instead consists of these asynchronously invoked agents. Much is made of event-driven programming environments like Windows, but in reality it's not much different from what we're doing here.

Having taken this walk through the pseudocode, you should now be able to fully understand the actual Intel source code in \SRC\TSREXAMP.C, Listing 9-15. However, many of the variable and function names are different in the pseudocode, and we haven't yet explained the sections which are conditionally compiled with #ifdef DOSSWAP.

TSREXAMP.C includes the rather cumbersome, but necessary, TSR.H which contains typedefs and function prototypes for all the modules that make up the generic TSR. Listing 9-16 shows TSR.H.

Listing 9-15: TSREXAMP.C

```
/*
TSREXAMP.C
by Raymond J. Michels
with revisions by Andrew Schulman

Second Edition - includes MS-DOS Task Manager/Windows Support
*/

#include <stddef.h>
#include <stdlib.h>
#include <stdio.h>
#include <conio.h>
#include <dos.h>
#include <bios.h>
#include <memory.h>
#include "tsr.h"

#define STACK_SIZE      8192  /* must be 16 byte boundary */
#define SET_DTA         0x1a  /* SET Disk Transfer Address */
#define GET_DTA         0x2f  /* GET Disk Transfer Address */

#define DOS_EXIT        0x4C   * DOS term nate (exit) */

#define KEYBOARD_PORT   0x60   * KEYBOARD Data Port */

#define PSP_TERMINATE   0x0A  /* Terminat on addr  in our PSP */
#define PSP_PARENT_PSP  0x16  /* Parent's PSP from  our PSP */
#define PSP_ENV_ADDR    0x2c  /* environment address from PSP */

#define HOT_KEY         32    /* Hot key a ong with ALT (D)*/

#define RIGHT_SHIFT     1
#define LEFT_SHIFT      2
#define CTRL_KEY        4
#define ALT_KEY         8

#define MULTIPLEX_ID    0xCD
#define INSTALL_CHECK   0x00
```

```
#define INSTALLED       0xFF
#define DEINSTALL       0x01
#define SESSION_ACTIVE  0x03

#define PARAGRAPHS(x)   ((FP_OFF(x) + 15) >> 4)

unsigned char multiplex_id = MULTIPLEX_ID,
char far *stack_ptr;            /* pointer to TSR stack */
unsigned ss_save,               /* slot for stack segment register */
unsigned sp_save,               /* slot for stack pointer register */
volatile int int_28_in_progress = 0;    /* true if INT 28h in progress */
volatile int unsafe_flag = 0,           /* true if INT 15h in progress */
unsigned keycode;
char buf[20],                   /* work buffer */
unsigned long TerminateAddr,    /* used during de-install */
union REGS regs;                /* register work structures */
struct SREGS sregs,
int hot_key,                    /* keycode for activation */
int shift_key,                  /* shift status bits (alt,  ctrl..) */
int user_key_set = 0,

/* Save areas for old interrupt pointers */
INTVECT old_int8, old_int9, old_int10, old_int15,
INTVECT old_int28, old_int2f;

#ifdef DOS_SWAP
extern int dos_critical;     /* used by DOSSWAP.C */
INTVECT old_int2a,
void interrupt far new_int2a(INTERRUPT_REGS);
#endif

extern int enhanced_windows,
extern int switcher_critical;

/* Global Data block that will be maintained in Instance Memory
   That way each session in a Task Manager will have unique Global
   Data. */

struct
{
    volatile int tsr_already_active,    /* true if TSR active */
    volatile int popup_while_dos_busy,  /* true if hotkey hit while dos busy */
    int breakState,                     /* status of MS-DOS break checking */
        INTVECT old_int1b, old_int23, old_int24,
    unsigned foreground_psp;            /* PSP of process we've interrupted */
    unsigned foreground_dta_seg;        /* DTA of process we've interrupted */
    unsigned foreground_dta_off;
    struct ExtErr ErrInfo,              /* save area for extended error info */
} TsrGlb;

int global_tsr_active   0,              /* flag to indicate a session is in TSR */

/* PROTOTYPES FOR THIS MODULE */
void interrupt far new_int8(INTERRUPT_REGS),
void interrupt far new_int9(INTERRUPT_REGS),
extern void interrupt far new_int13(void),  /* in TSRUTIL.ASM */
void  interrupt far new_int1b(INTERRUPT_REGS),
void interrupt far new_int23(INTERRUPT_REGS),
void interrupt far new_int24(INTERRUPT_REGS),
void interrupt far new_int28(INTERRUPT_REGS),
void  interrupt far new_int2f(INTERRUPT_REGS),
void tsr_function(void),
void tsr_exit(void),
void usage(char *);
int UnLinkVect(int Vect, INTVECT NewInt, INTVECT OldInt),
void parse_cmd_line(int argc, char *argv[]);
void main(int argc,char *argv[]);

/**********
* TIMER INTERRUPT HANDLER
```

```
**********/
void interrupt far new_int8(INTERRUPT_REGS r)
{
    (*old_int8)();      /* process timer tic */
#ifdef DOS_SWAP
    if (!TsrGlb.tsr_already_active && TsrGlb.popup_while_dos_busy &&
        !dos_critical && !unsafe_flag)
#else
    if (!TsrGlb.tsr_already_active && TsrGlb.popup_while_dos_busy &&
        !DosBusy() && !unsafe_flag)
#endif
    {
        /* If we're not running enhanced mode windows, set flag so that
           task swap will not occur. If we're not running Windows,
           enhanced defaults to true, so there is no effect  */
        if (!enhanced_windows)
            switcher_critical++,  /* don't allow task switch */
        TsrGlb.popup_while_dos_busy = 0,
        TsrGlb.tsr_already_active = 1,
        global_tsr_active = 1,
        _enable(); /* turn interrupts back on */
        tsr_function(),
        TsrGlb.tsr_already_active = 0;
            global_tsr_active = 0;
        if (!enhanced_windows)
            switcher_critical--, /* task switch ok */
    }
}
/**********
* KEYBOARD INTERRUPT HANDLER
**********/
void interrupt far new_int9(INTERRUPT_REGS r)
{
    if (!TsrGlb.tsr_already_active)
    {
        if ((keycode = inp(KEYBOARD_PORT)) != hot_key)
            _chain_intr(old_int9),
        if ((_bios_keybrd(_KEYBRD_SHIFTSTATUS) & shift_key) == shift_key)
        {
#ifdef USES_DISK
            if (!unsafe_flag)
            {
#endif
                TsrGlb.popup_while_dos_busy = 0,
                TsrGlb.tsr_already_active = 1,
                global_tsr_active = 1,
                (*old_int9)();      /* send key to old int routine */
                tsr_function(),
                TsrGlb.tsr_already_active = 0,
                global_tsr_active = 0;
#ifdef USES_DISK
            }
            else
            {
                TsrGlb.popup_while_dos_busy = 1,
                _chain_intr(old_int9),
            }
#endif
        }
        else
            _chain_intr(old_int9);
```

```
    }
    else
        _chain_intr(old_int9);
}
/*********
* CTRL-BREAK INTERRUPT HANDLER
*********/
void interrupt far new_int1b(INTERRUPT_REGS r) { /* do nothing */ }
/**********
* CTRL-C INTERRUPT HANDLER
**********/
void interrupt far new_int23(INTERRUPT_REGS r) { /* do nothing */ }
/**********
* CRTITICAL ERROR INTERRUPT HANDLER
**********/
void interrupt far new_int24(INTERRUPT_REGS r)
{
    if (_osmajor >= 3)
        r.ax = 3;   /* fail dos function */
    else
        r.ax = 0;
}
/**********
* DOS IDLE INTERRUPT HANDLER
**********/
void interrupt far new_int28(INTERRUPT_REGS r)
{
    int_28_in_progress++;
#ifdef DOS_SWAP
    if (TsrGlb.popup_while_dos_busy && !dos_critical
        && !TsrGlb.tsr_already_active && !unsafe_flag)
#else
    if (TsrGlb.popup_while_dos_busy && (!Int28DosBusy())
        && !TsrGlb.tsr_already_active && !unsafe_flag)
#endif
    {
        TsrGlb.tsr_already_active = 1;
        global_tsr_active = 1;

        tsr_function();
        TsrGlb.tsr_already_active = 0;
        global_tsr_active = 0;

    }
    int_28_in_progress--;
    _chain_intr(old_int28);
}
#ifdef DOS_SWAP
/*********
* DOS INTERNAL INTERRUPT HANDLER
*********/
void interrupt far new_int2a(INTERRUPT_REGS r)
{
   switch (r.ax & 0xff00)
   {
      case 0x8000:    /* start critical section */
         dos_critical++;
         break;
      case 0x8100:    /* end critical section */
      case 0x8200:    /* end critical section */
         if (dos_critical)    /* don't go negative  */
            dos_critical--;
         break;
```

```
        default:
            break;
    }
    chain_intr(old_int2a);
}
#endif
/*********
* DOS MULTIPLEX INTERRUPT HANDLER
*********/
void interrupt far new_int2f(INTERRUPT_REGS r)
{
    if (process_switcher_int2f(&r)) /* check if task switcher function */
    {
       unsigned ah = r.ax >> 8;
       unsigned al = r.ax & 0xFF;
       if (ah == multiplex_id)
       {
           if (al    INSTALL_CHECK)
               r.ax |= INSTALLED;
           else if (al == DEINSTALL)
           {
               if (global_tsr_active)
               /* a session is active, don't allow de-install */
               {
                    r.ax &= 0x1100;
                    //let caller know  we're still there
                    r.ax |= SESSION_ACTIVE;
               }
               else
               {
                    // because of stack swap, pass arg in static variable
                    terminateAddr = ((long)r.bx << 16) + r.dx;
                    if (! TsrGlb.tsr_already_active)
                    /* don't exit if we're active */
                    {
                        _enable(); /* STI */
                        tsr_exit();
                        // If we got here, we weren't able to unlink
                        // let caller know we're still there
                        r.ax = 0xFFFF;
                        // MSC 6.0 /Ox optimizes out the above
                        // get it back by using the value in ax
                        TsrGlb.tsr_already_active = -r.ax;
                        //set to 1 to prevent any more action
                    }
               }
           }
       }
       else
            chain_intr(old_int2f);
    }
}
/**********
* TSR ACTIVE SECTION
**********/
void tsr_function()
{
    switcher_critical++;
    windows_begin_critical();
    set_stack();
    windows_end_critical();
    switcher_critical--;
```

```
#ifdef DOS_SWAP
    if (SaveDosSwap() && !int_28_in_progress)
#else
    if (DosBusy() && !int_28_in_progress)
#endif
        /* set flag: next INT 8,28 activates us */
        TsrGlb.popup_while_dos_busy = 1;
    else
    {
        TsrGlb.popup_while_dos_busy = 0;

        /* save current extended break status */
        TsrGlb.breakState = GetBreak();

        /* set extended break status to be off */
        SetBreak(0);

#ifndef DOS_SWAP
        /* Get Extended Error Information */
        GetExtErr(&TsrGlb.ErrInfo);
#endif

        /* save old interrupt-CTRL-BREAK, CTRL-C and CRIT ERROR */
        TsrGlb.old_int1b = _dos_getvect(0x1b);
        TsrGlb.old_int23 = _dos_getvect(0x23);
        TsrGlb.old_int24 = _dos_getvect(0x24);

        /* set our interrupts functions */
        _dos_setvect(0x1b, new_int1b);
        _dos_setvect(0x23, new_int23);
        _dos_setvect(0x24, new_int24);

        /* not needed for DOSSWAP, but can be used by application */
        TsrGlb.foreground_psp = GetPSP();

        SetPSP(_psp);   // _psp in STDLIB.H

#ifndef DOS_SWAP
        /* get foreground DTA */
        regs.h.ah = GET_DTA;
        intdosx(&regs, &regs, &sregs);
        TsrGlb.foreground_dta_seg = sregs.es;
        TsrGlb.foreground_dta_off = regs.x.bx;
#endif

        /* set up our DTA */
        regs.h.ah = SET_DTA;
        regs.x.dx = 0x80;   /* use default in PSP area */
        sregs.ds = _psp;
        intdosx(&regs, &regs, &sregs);

        /* suck up key(s) in buffer */
        while (_bios_keybrd(_KEYBRD_READY))
           _bios_keybrd(_KEYBRD_READ);

        /* your code goes here */
        application();
#ifdef DOS_SWAP
        /* put back original INTS */
        _dos_setvect(0x1b, TsrGlb.old_int1b);
        _dos_setvect(0x23, TsrGlb.old_int23);
        _dos_setvect(0x24, TsrGlb.old_int24);

        /* put back extended error information */
        SetExtErr(&TsrGlb.ErrInfo);
```

```
        RestoreDosSwap();
#else

        /* put back original DTA */
        regs.h.ah = SET_DTA;
        regs.x.dx = TsrGlb.foreground_dta_off;
        sregs.ds  = TsrGlb.foreground_dta_seg;
        intdosx(&regs, &regs, &sregs);

        /* put back original PSP */
        SetPSP(TsrGlb.foreground_psp);

        /* put back original INTS */
        _dos_setvect(0x1b, TsrGlb.old_int1b);
        _dos_setvect(0x23, TsrGlb.old_int23);
        _dos_setvect(0x24, TsrGlb.old_int24);

        /* put back extended error information */
        SetExtErr(&TsrGlb.ErrInfo);
#endif


        /* put back extended break checking the way it was */
        SetBreak(TsrGlb.breakState);


    }

    switcher_critical++;
    windows_begin_critical();

    restore_stack();

    windows_end_critical();
    switcher_critical--;
}

// only restores OldInt if someone hasn't grabbed away Vect
int UnlinkVect(int Vect, INTVECT NewInt, INTVECT OldInt)
{
    if (NewInt == _dos_getvect(Vect))
       { _dos_setvect(Vect, OldInt); return 0; }
    return 1;
}

void tsr_exit(void)
{
    set_stack();
    /* put interrupts back the way they were, if possible */
    if (!(UnlinkVect(8, new_int8, old_int8)    |
        UnlinkVect(9, new_int9, old_int9)        // Do not use ||, we
        UnlinkVect(0x28, new_int28, old_int28) | // DON'T want early out
        UnlinkVect(0x13, new_int13, old_int13) |
#ifdef DOS_SWAP
        UnlinkVect(0x2a, new_int2a, old_int2a) |
#endif
        UnlinkVect(0x2f, new_int2f, old_int2f) ))
    {
        // Set parent PSP, stored in our own PSP, to the current PSP
        *(int far *)(((long _psp << 16) + PSP_PARENT_PSP) = GetPSP();

        // Set terminate address in our PSP
        *(long far *)(((long _psp << 16) + PSP_TERMINATE) = TerminateAddr;

        SetPSP(_psp); /* set psp to be ours */

        bdos(DOS_EXIT, 0, 0); /* exit program */
    }
    restore_stack();
}
```

```
void usage(char *progname)
{
    fputs("Usage: ", stdout);
    puts(progname);
    puts("  [-d deinstall] [-k key shift-keys] [-f multiplex id]");
    puts("Valid multiplex id");
    puts("     00 through 15 specifies a unique INT 2Fh ID");
    puts("Valid shift-keys is any combination of:");
    puts("    1 = Right Shift");
    puts("    2 = Left Shift");
    puts("    4 = CTRL");
    puts("    8 = ALT");
    exit(1);
}
void do_deinstall(char *progname)
{
    fputs(progname, stdout);
    switch (deinstall())
    {
        case 1
            puts(" was not installed"), break,
        case 2
            puts(" deinstalled"); break;
        case SESSION_ACTIVE
            puts(" TSR active in another session. "
                "TSR was not deinstalled"), break,
        default
            puts(" deactivated but not removed"); break,
    }
    exit(0);
}
int set_shift_key(unsigned sh)
{
    /* figure out, report on shift statuses */
    /* make sure shift key < 0x10 and non-zero */
    if ((shift_key = sh) < 0x10) && shift_key)
    {
        printf( Activation  %s%s%s%s(AN>%d\n",
            shift_key & RIGHT_SHIFT ? "RIGHT " : "",
            shift_key & LEFT_SHIFT ? "LEFT " : "",
            shift_key & CTRL_KEY ? "CTRL " : "",
            shift_key & ALT_KEY ? "ALT " : "",
            hot key);
        return 1;
    }
    else /* error, bad param */
    {
        puts("Invalid Shift-Status");
        return 0;
    }
}
void parse_cmd_line(int argc, char *argv[])
{
    int i;
    int tmp;
    for (i = 1; i < argc; i++)   /* for each cmdline arg */
        if ((argv[i][0] == '-') || (argv[i][0] == '/'))
            switch(toupper(argv[i][1]))
            {
                case 'D':
                    do_deinstall(argv[0]);
                    break;
                case 'K':    /* set pop up key sequence */
```

```
                user_key_set = 1;
                i++;     /* bump to next    argument */
                if ((hot_key = atoi(argv[i])) != 0)
                {
                    i++;   /* bump to next argument */
                    if (!set_shift_key(atoi(argv[i])))
                        usage(argv[0]);
                }
                else
                    usage(argv[0]);
                break;
            case 'F':   /* set multiplex ID */
                i++,    /* bump to next argument */
                if ((tmp = atoi(argv[i])) < 0x10)
                    multiplex_id += tmp; /* range of C0-CF */
                else
                    usage(argv[0]),
                break;
            default:    /* invalid argument */
                usage(argv[0]),
        }   /* end switch */
    else
        usage(argv[0]),
}
void FAIL(char *s) { puts(s); exit(1); }
void main(int argc,char *argv[])
{
    union REGS  regs,
    struct SREGS sregs,
    unsigned far *fp;
    unsigned memtop, dummy,
    int ret_value,
    /* initialize flags */
    TsrGlb.popup_while_dos_busy = 0;
    TsrGlb.tsr_already_active = 0,
    InitInDos(),

    /* the following must be called before adding instance data */
    init_switchar_structures(),
    parse_cmdline(argc,argv),
    /* check if TSR already installed! */
    regs.h.ah = multiplex_id;
    regs.h.al = INSTALL_CHECK,
    int86(0x2f, &regs, &regs);
    if (regs.h.al == INSTALLED)
    {
        puts("TSR already installed"),
        fputs(argv[0], stdout); puts(" -D de installs");
        exit(1);
    }
    if (! user_key_set)
    {
        puts("Press ALT-D to activate TSR "),
        printf("Multiplex ID = %0x \n",multiplex_id);
        hot_key = HOT_KEY,
        shift_key = ALT_KEY,
    }
#ifdef DOS_SWAP
    if ((ret_value = InitDosSwap()) != 0,
    {
```

```
        puts("Error initializing DOS Swappable Data Area");
        switch (ret_value)
        {
            case 1:
                puts("No Available Memory"), break,
            case 2:
                puts("Too Many Swap Blocks"), break,
            case 3:
                puts("Unsupported DOS"); break,
            case 4:
                puts("Unable to add swap blocks to instance memory"),
                break;
            default,
                puts("Failure Return from GetDosSwap Call"), break,
        }
        exit(1);
    }
#endif
    /* MALLOC a stack for our TSR section */
    if ((stack_ptr = malloc(STACK_SIZE)) == NULL)
        FAIL("Unable to allocate stack"),
    if (add_instance_block(stack_ptr, STACK_SIZE))
        FAIL("Unable to add stack to instance data"),
    stack_ptr += STACK_SIZE;
    if (add_instance_block(&TsrGlb, sizeof(TsrGlb)))
        FAIL("Unable to add TSR global data to instance data"),
    if (add_instance_block(&ss_save, sizeof(ss_save)))
        FAIL("Unable to add ss_save global data to instance data"),
    if (add_instance_block(&sp_save, sizeof(sp_save)))
        FAIL("Unable to add sp_save global data to instance data"),
    if (add_instance_block(&stack_ptr, sizeof(stack_ptr)))
        FAIL("Unable to add stack_ptr global data to instance data"),
    if (add_instance_block(&regs, sizeof(regs)))
        FAIL("Unable to add regs global data to instance data");
    if (add_instance_block(&sregs, sizeof(sregs)))
        FAIL("Unable to add sregs global data to instance data"),
     /* check if windows running */
    check_windows_running();
     /* check if task switcher running */
    check_switcher_running();
    /* get interrupt vector */
    old_int8  = _dos_getvect(8),      /* timer interrupt */
    old_int9  = _dos_getvect(9);      /* keyboard interrupt */
    old_int13 = _dos_getvect(0x13),   /* disk intr,  in TSRUTIL.ASM */
    old_int28 = _dos_getvect(0x28);   /* dos idle */
    old_int2f = _dos_getvect(0x2f);   /* multiplex int */
#ifdef DOS_SWAP
    old_int2a = _dos_getvect(0x2a),   /* dos internal int */
#endif
    init_intr(),  /* initialize int routines in TSRUTIL.ASM */

    /* set interrupts to our routines */
    _dos_setvect(8, new_int8),
    _dos_setvect(9, new_int9),
    _dos_setvect(0x13, new_int13),      /* in TSRUTIL.ASM */
    _dos_setvect(0x28, new_int28),
    _dos_setvect(0x2f, new_int2f),
#ifdef DOS_SWAP
    _dos_setvect(0x2a, new_int2a),
#endif
```

```
    /* release environment back to MS-DOS */
    FP_SEG(fp) = _psp;
    FP_OFF(fp) = PSP_ENV_ADDR;
     dos_freemem(*fp);
    /* release unused heap to MS-DOS */
    /* ALL MALLOCS for TSR section must be done in  TSR_INIT() */
    /* calculate top of memory, and go TSR */
    segread(&sregs);
    memtop = sregs.ds + PARAGRAPHS(stack_ptr) -  psp;
    _dos_keep(0, memtop);
}
```

Listing 9-16: TSR.H

```
/* TSR Prototype file and common variables */

#ifdef  cplusplus
extern "C" {
#endif

#define INTERRUPT void interrupt far

typedef struct {
#ifdef TURBOC
    unsigned bp, di, si, ds, es, dx, cx, bx, ax;
#else
    unsigned es, ds;
    unsigned di, si, bp, sp, bx, dx, cx, ax;    /*  PUSHA */
#endif
    } INTERRUPT_REGS;

typedef void (interrupt far *INTVECT)();

/* Prototypes for functions in INDOS.C */
int   DosBusy(void);
int   Int28DosBusy(void);
void  InitInDos(void);

/* Prototypes for functions in PSP.C */
unsigned GetPSP(void);
void  SetPSP(unsigned segPSP);

 * Prototypes for functions in TSRUTIL.ASM */
int   far   deinstall(void);
void  far   init_intr(void);
void  far   idle_int_chain(void);

void  interrupt far   new_int10(void);
void  interrupt far   new_int13(void);
void  interrupt far   new_int25(void);
void  interrupt far   new_int26(void);

void  far   timer_int_chain(void);

/* Prototypes for functions in STACK.ASM */
void  far   set_stack(void);
void  far   restore_stack(void);

/* Prototypes for functions in EXTERR.C */
void  GetExtErr(struct ExtErr * ErrInfo);
void  SetExtErr(struct ExtErr * ErrInfo);

struct   ExtErr
{
   unsigned int errax, errbx, errcx, errdx, errsi, errdi;
   unsigned int errds, erres;
   unsigned int reserved, userID, programID,
};

/* Prototypes for functions in DOSSWAP.C */
```

```
int   InitDosSwap(void),
int   SaveDosSwap(void),
void  RestoreDosSwap(void);

/* Pointer defined in INDOS.C */
extern char far *   indos_ptr,
extern char far *   crit_err_ptr;

/* Prototypes for functions in BREAK.C */
int GetBreak(void);
void SetBreak(int breakStatus),

/* Prototypes and global vars defined in SWITCHER.C */
extern int  enhanced_windows,
extern int  switcher_critical,

int   process_switcher_int2f(INTERRUPT_REGS far *r),
void    init_switcher_structures(void),
int add_instance_block(void far *ptr, unsigned int size),
void windows_begin_critical(),
void windows_end_critical(),
void check_windows_running(void);
void check_switcher_running(void),

#ifdef __cplusplus
}
#endif
```

Many readers of the first edition of this book noticed an error in the installation of INSRTXAMP.C. We were incorrectly calling RestoreDosSwap before having restored original interrupt handlers. Since DOS sometimes generates an INT 24h (Critical Error Handler) when DOS calls are made, it potentially damages the state of DOS after we have called RestoreDosSwap. We should call RestoreDosSwap only after all DOS calls are made. This has been corrected in Listing 9-15.

Finally, there's INSRUTIL.ASM (Listing 9-17), which contains miscellaneous routines that we either didn't want to write in C, or couldn't:

Listing 9-17: TSRUTIL.ASM

```
;TSRUTIL.ASM

;Define segment names used by C

;
_TEXT   segment byte public 'CODE'
_TEXT   ends

CONST   segment word public 'CONST'
CONST   ends

_BSS    segment word public 'BSS'
_BSS    ends

_DATA   segment word public 'DATA'
_DATA   ends

DGROUP  GROUP   CONST, _BSS, _DATA

    assume  CS:_TEXT, DS:DGROUP

    public  _new_int13, _init_intr
IFDEF MULTI
    public  _timer_int_chain
    public  _new_int10, _new_int21, _new_int25,  new int26
ELSE
    public  _deinstall
ENDIF

    extrn   _ss_save near       ;save foreground SS
    extrn   _sp_save near       ;save foreground SP
    extrn   _unsafe_flag:near   ;if true, don't interrupt
    extrn    old int13 near
```

```
IFDEF MULTI
    extrn   old_int8:near
    extrn   _old_int10 near
    extrn   _old_int21 near
    extrn   _old_int25 near     ; note difference between
    extrn   _old_int26.near     ; old_int25 and _old_int25'
    extrn   dos_count:near
    extrn   _in_progress:near
ELSE
    extrn   _multiplex_id:near  ;our INT 2Fh id byte
ENDIF

_TEXT   segment

IFNDEF MULTI
;*****
;void far deinstall(void)
;function to use INT 2Fh to ask TSR to deinstall itself
;the registers are probably all changed when our tsr exits
;so we save them and perform the INT 2f  The TSR exit will
;eventually bring us back here  Then the registers are restored
;This function is called from the foreground, not the TSR

DEINSTALL   equ     1

_deinstall      proc    far
    push    si
    push    di
    push    bp
    mov     word ptr _ss_save,ss        ; save our stack frame
    mov     word ptr _sp_save,sp

    mov     cs:_ds_save,ds              ; save DS for later restore

    mov     bx,cs
    mov     dx, offset TerminateAddr, bx:dx points to terminate address
    mov     ah, byte ptr _multiplex_id
    mov     al, DEINSTALL
    int     2fh                         ; call our TSR
;
;if TSR terminates ok, we'll skip this code and return to Terminate Addr
;
    jmp     short NoTerminate

TerminateAddr:
;Restore DS and stack
    mov     bx,cs:_ds_save              ; bring back our data segment
    mov     ds,bx                       ; destroyed by int 2f

    mov     al,2                        ; Set value for success

    mov     ss, word ptr _ss_save       ; restore our stack
    mov     sp, word ptr _sp_save       ; destroyed by int 2f

NoTerminate:
    cbw                                 ;Extend return value to word
    pop     bp
    pop     di
    pop     si
    ret
_deinstall endp
ENDIF

;*****
;void inc_unsafe_flag(void) - increment unsafe flag
;*****
;
inc_unsafe_flag proc    far
    push    ax
    push    ds
    mov     ax,DGROUP                   ;make DS = to our TSR C data segment
    mov     ds,ax
```

```
    inc     word ptr _unsafe_flag
    pop     ds                          ;put DS back to whatever it was
    pop     ax
    ret
inc_unsafe_flag endp
;*****
;void dec_unsafe_flag(void)   decrement unsafe flag
;*****
dec_unsafe_flag proc    far
    push    ax
    push    ds
    mov     ax,DGROUP                   ;make DS = to our TSR C data segment
    mov     ds,ax
    dec     word ptr _unsafe_flag
    pop     ds                          ;put DS back to whatever it was
    pop     ax
    ret
dec_unsafe_flag endp
;we can't trap the following interrupts in C for a number of
;reasons
;   INT 13 returns info in the FLAGS, but a normal IRET
;   restores the flags
;
;   INT 25 & 26 leave the flags on the stack. The user
;   must pop the off after performing an INT 25 or 26
;
;   These interrupts pass information via registers such
;   as DS. We don't want to change DS.
;
;   Since DS is unknown, we must call the old interrupts
;   via variables in the code segment  The _init_intr routine
;   sets up these CS variables from ones with nearly-identical
;   names in the C data segment in TSREXAMP.C.
;*****
;void far init_intr(void)
;move interrupt pointer saved in the C program to our CS data area
;*****
; note confusing distinction between e g  _old_int13 and old_int13
SET_OLD MACRO _old_int, old_int
    les  bx, dword ptr _old_int
    mov  word ptr cs:old_int, bx
    mov  word ptr cs:old_int+2, es
    ENDM
_init_intr proc far
     push    es
     push    bx
IFDEF MULTI
     SET_OLD _old_int10, old_int10
     SET_OLD _old_int21, old_int21
     SET_OLD _old_int25, old_int25
     SET_OLD _old_int26, old_int26
ENDIF
     SET_OLD _old_int13, old_int13
     pop     bx
     pop     es
     ret
_init_intr endp
;*****
;void far new_int13(void) - disk interrupt
;*****
```

```
_new_int13 proc far
    call    inc_unsafe_flag
    pushf                               ;simulate interrupt call
    call    cs:old_int13
    call    dec_unsafe_flag
    ret     2                           ; leave flags intact
_new_int13 endp
IFDEF MULTI
;*****
;void far new_int21(void) - dos interrupt
;*****
_new_int21 proc far
    sti
;see if function 0. if so jump to int 21h vector
    cmp     ah,0
    jne     int21_0
    jmp     cs:old_int21
int21_0:
    push    ds
    push    ax
    mov     ax, DGROUP
    mov     ds,ax
    cmp     word ptr [_in_progress], 0
    je      int21_1                     ;not in background, so skip next
    inc     word ptr _dos_count         ;flag that the background has called dos
int21_1:
    pop     ax
    pop     ds
    pushf                               ;simulate interrupt call
    call    cs:old_int21
    pushf
    push    ds
    push    ax
    mov     ax, DGROUP
    mov     ds,ax
    cmp     word ptr [_in_progress], 0
    je      int21_2                     ;not in background, so skip next
    dec     word ptr _dos_count
int21_2:
    pop     ax
    pop     ds
    popf
    ret     2
_new_int21 endp
;*****
;void far new_int10(void)   video interrupt
;*****
_new_int10 proc far
    call    inc_unsafe_flag
    pushf                               ;simulate interrupt call
    call    cs:old_int10
    call    dec_unsafe_flag
    iret
_new_int10 endp
;*****
;void far new_int25(void)   MS-DOS absolute sector read
;*****
```

```
_new_int25  proc far
    call    inc_unsafe_flag
    call    cs:old_int25
    call    dec_unsafe_flag
    ret                                 ; user must pop flags - MS-DOS convention
                                        ; so leave them on the stack
_new_int25 endp
;*****
;void far new_int26(void) - MS-DOS absolute sector write
;*****
_new_int26 proc far
    call    inc_unsafe_flag
    call    cs old_int26
    call    dec_unsafe_flag
    ret                                 ; user must pop flags - MS-DOS convention
                                        ; so leave them on the stack
_new_int26 endp
;*****
;void far timer_int_chain(void) - jump to next timer ISR
;we need to clean up the stack because of this call
;*****
_timer_int_chain proc far
    mov         _ax_save,ax
    pop         ax
    pop         ax
    mov         ax, _ax_save
    jmp         dword ptr _old_int8
_timer_int_chain    endp
END}f

;
;save areas for original interrupt vectors
;
IFDEF MULTI
old_int10   dd  0       ;video
old_int21   dd  0       ;dos int
old_int25   dd  0       ;sector read
old_int26   dd  0       ;sector write
ENDIF
old_int13   dd  0       ;disk

_ds_save    dw  0
_TEXT   ends

_DATA   segment
IFDEF MULTI
_ax_save    dw  0
ENDIF
_DATA   ends

    end
```

TSR Command Line Arguments

Any program built with the generic TSR can take optional command line arguments that set its hotkey and its multiplex number. A command line option is also available to deinstall the TSR. The implementation of which will be discussed in detail later on.

The command line syntax is: tsrname [-k scan shift] [-i multiplex id] [-d deinstall]. A valid shift status is any combination of:

1 = Right Shift
2 = Left Shift
4 = CTRL
8 = ALT

Available multiplex IDs (C0h through FFh) and specifies a unique INT 2Fh ID starting at AH=C0h.

The default hotkey is Alt-F1 and the default multiplex ID is C0h, which turns into INT 2Fh Function C0h. Specifying a different hotkey and a different multiplex ID makes it possible to simultaneously run multiple programs loaded with the same TSR. Finally, to demonstrate a TSR whose multiplex ID is not the default, you must specify the /m switch and the /i and /d switches. For example:

```
C:\UNDOC2\CHAP9>tsrdisp /k 59 8
    TSRFILE hotkey is Alt-F1 (F1 decimal scancode is 59)
    TSRFILE multiplex ID is default C0h

C:\UNDOC2\CHAP9>tsrmem /k 60 4 /i 1
    TSRMEM hotkey is Ctrl-F2 (F2 decimal scancode is 60)
    TSRMEM multiplex ID is C1h

C:\UNDOC2\CHAP9>tsrmem /i 1 /d
    TSRMEM deinstalled
```

Writing TSRs with the DOS Swappable Data Area

Undocumented INT 21h Function 5D06h for DOS versions 3.x as well as for DOS 5.0 and higher and Function 5D0Bh for DOS 4.x provide access to the DOS SDA. This block of data contains most of the variables that MS-DOS uses to keep track of its internal context. The SDA includes the current PSP address, the three MS-DOS stacks as discussed earlier, and as shown in gory detail in the appendix to the *Undocumented DOS* book, DOS's data buffers. The SDA is DOS's data. For example, when you call INT 21h Function 5Fh (INT 21h Function 62h returns the current PSP where do you think it gets it from? From the SDA, of course!) Undocumented DOS maps out each of DOS's three stacks in the book's SDA. Once you have the SDA, you can make extensive use of the SDA in your TSR programs that use undocumented DOS. The SDA is a large chunk of the DOS data segment. In DOS 4.0 only, there can be multiple SDAs.

After a quick call to Function 5D06h, the SDA is located. For DOS 4 versions, the actual structure of the SDA varies between versions 4.00 and 4.01, but is compatible between DOS 3.00 and 4.00.

What does the SDA have to do with TSRs? Plenty. Recall that we must worry about when there's no danger of invoking DOS when a TSR is activated by the user. The undocumented INT 2Ah Functions 5D00h and 5D0Bh (switch sector MS-DOS critical section) in the SDA. This allows you to call MS-DOS at times when the critical section flag is set. Many DOS functions indicate if a call to DOS is safe. We should note that the word "safe" is relative. Some DOS functions are safe to call only if you're not calling the SDA can never be 100% certain. Since the SDA is a large chunk of DOS data, it encompasses a lot of DOS' state. On the contrary, in the first edition of this book, encompass all of DOS' state.

The first two functions are the familiar INT 2Ah "Net" critical section calls. INT 2Ah Function 5D06h is invoked when DOS is about to enter a critical section. When DOS is in a critical section, you cannot change the SDA. Function 5D0Bh is invoked when DOS leaves a critical section. INT 2Ah Functions 81h or 82h. Note that INT 2Ah is not supported by MS-DOS 3.x versions or earlier.

While the concept of INT 2Ah is great, the INT 2Ah calls do have one major drawback. It can be most conspicuously demonstrated by the program shown in Listing 9-18 in conjunction with the INTRSPY program presented in Chapter 5.

Listing 9-18: CRITSECT.SCR Watches INT 2Ah Critical Section Calls

```
;; CRITSECT.SCR -- trap INT 2Ah critical section entry/exit calls
intercept 2Ah
    function 80h on_entry output "ENTER CRIT " al
    function 81h on_entry output "EXIT CRIT " al
    function 82h on_entry output "EXIT ALL CRIT
```

Running this script and leaving it loaded for as long as you like while running programs in native DOS will yield no results other than a lot of calls to INT 2Ah AH=82h when it exits a critical sections. This call comes from the INT 21h dispatch code we examined in chapter 6. But we never see any critical sections being entered! This is because, while DOS has code to generate these calls at the appropriate times, it is normally disabled and requires patches to enable it. These patches vary, perhaps unsurprisingly, between versions of DOS. Windows and network shells perform the necessary patches and use the resultant calls in just the way we need to for the case of Windows 3 but do not make the calls available outside a DOS box by adding the line ReflectDosInt2A=1 to the SYSTEM.INI file. The CRITSECT script when run in a DOS box will be much more productive. The CRITSECT program in Listing 9-19 allows the necessary patches to be applied and removed by invoking the program with ON or OFF on the command line.

Listing 9-19: CRITSECT.C

```
/*
CRITSECT.C
Andrew Schulman, January 1993
from  Undocumented DOS , 2nd edition (Addison-Wesley, 1993)

Thanks to John Brennan (John.Brennan@vlsi.fr.cmu.edu)
and to Norman D. Culver (CIS 70672,1257)

Reports on DOS critical sections, turns off or on

Table of critical section patch offsets at:
DOS:02C3h in DOS 3.1-3.3
DOS:0315h in DOS 4, 5, 6

to turn ON critical section calls in DOS
in DOS 3-4, poke in 50h (PUSH AX) to replace C3h (RET)
in DOS 5-6, poke in any non-zero value
*/

#include <stdlib.h>
#include <stdio.h>
#include <string.h>
#include <dos.h>

#ifndef MK_FP
#define MK_FP(seg, ofs) \
    ((void far *) (((unsigned long) (seg) << 16) | (ofs)))
#endif

// get DOS data segment
// call 21/52 (Get List of Lists), keep segment, discard offset
unsigned short get_dos_ds(void)
{
    _asm push es
    _asm xor ax, ax
    _asm mov es, ax
    _asm mov ax, 5200h
    _asm int 21h
    _asm mov ax, es
    _asm pop es
    // return value in AX
}

// get DOS version number
// if DOS 5+, use 21/3306 because of SETVER
void get_dos_version(unsigned char *pmaj, unsigned char *pmin)
{
    unsigned char maj, min;
    // must call 21/3306 before 21/30, but don't know if 21/3306 supported!
    // best bet is to clear BX beforehand, unsupported should set AL=FFh
    _asm xor bx, bx
    _asm mov ax, 3306h
```

```
    _asm int 21h
    _asm mov maj, b.
    _asm mov min, bh
    if ((maj==0) &&  min==0))
    {
        _asm mov ax, 3000h
         asm int 21h
        _asm mov ma,, al
        _asm mov min, ah
    }
    *pmaj = ma,,
    *pmin = min,
}
void fail(char *s) { puts(s), exit(1); }
typedef enum { STATUS, ON, OFF } REQU,
main(int argc, char *argv[])
{
    unsigned short far *patch_tab,
    unsigned short far *p,
    unsigned char far *fpop;
    unsigned short dos_ds,
    unsigned short tab_ofs,
    unsigned char dos_maj, dos_min;
    char *s;
    unsigned char op,
    REQU requ;
    // command line:  ON, OFF, or (default) STATUS
    if (argc < 2)
        requ = STATUS;
    else
    {
        s   strupr(argv[1]),
        if (strcmp(s, "STATUS") == 0) requ = STATUS,
        else if (strcmp(s, "ON") == 0) requ = ON;
        else if (strcmp(s, "OFF") == 0) requ = OFF;
        else fail("usage. critsect [status | on | off]"),
    }
    // get DOS data segment
    dos_ds = get_dos_ds(),
    // get DOS version numbe      program works with DOS 3.1-6.0
    // may have to check for DR-DOS, etc.
    get_dos_vers(&dos_maj, &dos_min),
    if ((dos_maj < 3)  | (dos_maj > 6)  |  ((dos_maj  == 3) && (dos_min == 0)))
        fail("Unsupported DOS version");
    // get pointer to table
    tab_ofs = (dos_maj == 3) ? 0x02c3 : 0x0315,
    patch_tab    unsigned short far *  MK_FP(dos_ds, tab_ofs),
    if (requ == STATUS)
        printf("Critical sect.r pat h tab e at  %p\n , patch tab),
#define RET         0xC3
#define PUSH_AX     0x50
    // walk table
    for (p=patch_tab; *p !  0; p++)
    {
        fpop = (unsigned char far *) MK_FP(dos_ds, *p);
        op = *fpop;
        if (dos_maj < 5)
        {
            if (op == RET) s = "OFF";
            else if (op == PUSH_AX) s = "ON",
```

```
            else fail("Critical section patch table invalid!");
            if (requ == ON)         *fpop = PUSH_AX;
            else if (requ == OFF)   *fpop = RET;
        }
        else
        {
            if (op == 0) s = "OFF";
            else s = "ON";
            // no way to check for valid/invalid,
            // though anything other than 0 or 1 is suspicious

            if (requ == ON)         *fpop = 1;
            else if (requ == OFF)   *fpop = 0;
        }
        if (requ == STATUS)
            printf("%Fp = %02X  %s\n", fpop, op, s);
    }
    if (requ == ON) puts("Turned critical sections ON");
    else if (requ == OFF) puts("Turned critical sections OFF");
    return 0;
}
```

Once DOS is generating INT 2Ah critical section calls you will need to write an interrupt handler for INT 2Ah to keep track of critical sections. You can only swap the SDA when DOS isn't in a critical section.

Your INT 2Ah handler may be bypassed under Windows Enhanced mode because Windows patches DOS, turning its INT 2Ah calls into far calls into the Virtual Machine Manager (VMM). Microsoft's *MS DOS Programmer's Reference* for MS DOS 6 oldspeak refers to this when it says that MRC programs must acquire the Windows disk critical section by calling INT 2Fh AX=8001h and "Furthermore that calls to this function must be made in a particular way because Windows expects this exact sequence" (p. 446). The point is that Windows will patch the INT 2Fh AX=8001h so that it becomes a far call out to VMM, which implements its own Begin Critical Section and End Critical Section calls documented in the Windows DDK.

Returning to the SDA, INT 21h Function 5D06h returns the following pointers:

```
DS:SI   points to DOS swappable data area
DX      - size of area to swap when InDOS > 0
CX      - size of area to always swap
```

INT 21h Function 5D0Bh (for DOS 4 and higher) returns in DS:SI a pointer to an SDA list, which contains:

```
Offset    Size      Description
----      ----      -----------
00h       WORD      Count of SDAs
SDA ENTRY:
02h       DWORD     Address of this SDA
06h       WORD      Data area length and type
                    bit 15    - set if swap always
                                clear if swap while InDOS > 0
                    bits 14-0 - length in bytes
08h                 next SDA_ENTRY
```

To reiterate, these functions give you pointers to the data areas that contains much, but not all, of the information related to the current process as well as information specific to DOS's call that may be in progress. Since MS DOS switches stacks when invoked with INT 21h, it is seemingly not reentrant. But since the stacks are part of this data area, you can save this area's contents

by moving the entire swappable data area and immediately call DOS without fear of trashing DOS's internal stacks. Unfortunately, there are also key DOS variables that reside outside the part of the DOS data segment that is made available as the SDA.

In previous sections, we checked the DOS flags to determine whether it was safe to activate and, once activated, we saved the current PSP, DTA, and extended error information. Using the aDOSSWAP.ASM routine eliminates these steps. You can determine when it's safe to pop up by tracking the INT 2Ah critical section calls. If you are not in a critical section, it's safe to call DOS. If InDOS is zero, just save the data area that is always swapped (typically 158 bytes). If InDOS is non-zero, then the swappable data areas must be saved (typically 736 bytes, less than 2K).

The TSR saves the data to a memory block that was allocated during TSR initialization (see the InitDosSwap function in DOSSWAP.C). In your own TSR, this must be performed before the TSR stack is allocated. Once the data area has been saved, you set the current PSP and DTA values to those for your TSR. When it's time for the TSR to exit, you must move back the SDAs that we've saved. Since this data block contains the current PSP, DTA, and extended error information, we don't need to deal directly with these values.

Note: At the time of this writing, it's not clear whether the DOS SDA list returned by function 5D06h is static when MS-DOS is booted or whether it is changed dynamically during the course of MS-DOS execution. It appears that functions 5D06h and 5D0Bh return identical information for MS-DOS 4.x. Since function 5D0Bh won't work on pre-DOS 5 systems, DOS 4.0 is the only phenomenon that I've had a hard time totally grasping. Frankly, function 5D0Bh seeks to be just another example of how IBM added ever-complexity to DOS when the goal was to lend support to version 4.0.

The C module in Listing 9-20's contains functions for saving and restoring the DOS SDA.

Listing 9-20: SDA Save and Restore Module DOSSWAP.C

```
/* DOSSWAP.C   Functions to manage DOS swap areas */

#include <stdio.h>
#include <dos.h>
#include <memory.h>
#include  "tsr.h"
#include  "put.h"

#define GET_DOSSWAP3        0x5d06
#define GET_DOSSWAP4        0x5d0b

#define SWAP_LIST_LIMIT     20

struct  swap_list    /* format of DOS 4+ SDA list */
{
    void far* swap_ptr;
    int swap_size;
},
/* variables for 3.x swap work */
static        char     far * swap_ptr,  /* pointer to dos swap area */
static        char     far * swap_save; /* pointer to our local save area */
static         int     swap_size_indos,
static        int      swap_size_always,
static         int     size,
/* variables for 4.x swap work */
static int swap_count;      /* count of swappable areas */
static struct swap_list swp_list[SWAP_LIST_LIMIT];
/*.ist of swap areas*/
static char far *swp_save[SWAP_LIST_LIMIT],    * out save area */
static int swp_flag[SWAP_LIST_LIMIT],   /* flags if has been swapped */

static int dos_level,    /* for level dependent code */
int dos_critical;       /* in critical sect on, can't swap */
/*****
Function: InitDosSwap
```

```
Initialize pointers and sizes of DOS swap area.
Return zero if success
       1    - no memory
       2    - too many swap lists
       3    - unsupported dos
       4    - too many instance memory blocks
*****/
int InitDosSwap(void)
{
    union  REGS regs;
    struct SREGS segregs;
    int    ret;

     /* establish what dos level we're running
       make sure that DOSVER is not setup for this TSR
     */
    if ((_osmajor == 3) && (_osminor >= 10))
        dos_level = 3;
    else if (_osmajor == 4)
        dos_level = 4;
     else if (_osmajor == 5 || _osmajor == 6) /* 5 =  6 for now */
        dos_level = 5;
    else
        dos_level = 0;

    if (dos_level == 3 || dos_level == 5)    /* use 2150D6 */
    {
        regs.x.ax = GET_DOSSWAP3;
        intdosx(&regs,&regs,&segregs);

        /* make sure no error occurred on interrupt function */
        if (regs.x.cflag)
            return('0');

        /* pointer to swap area is returned in DS:SI */
        FP_SEG(swap_ptr) = segregs.ds;
        FP_OFF(swap_ptr) = regs.x.si;

        swap_size_indos = regs.x.cx;
        swap_size_always= regs.x.dx;

        size = 0;  /* initialize for later */
        swap_save = malloc(swap_size_indos);

        ret = ((swap_save == 0) ? 3 : 0);

        /* if we got mem, then see if we can add instance */
        if (!ret && add_instance_block(swap_save, swap_size_indos))
            ret = 4;

        return(ret);

    }
    else if (dos_level >= 4)  /* use 5d0b */
    {
        struct swap_list far *ptr;
        int far *iptr;
        int i;
        regs.x.ax = GET_DOSSWAP4;
        intdosx(&regs,&regs,&segregs);

        /* make sure no error occurred on interrupt function */
        if (regs.x.cflag)
            return('0');

        /* pointer to swap list is returned in DS:SI */
        FP_SEG(iptr) = segregs.ds;
        FP_OFF(iptr) = regs.x.si;
        swap_count = *iptr;                    /* get size of list */
        iptr++;
```

```
        ptr = (struct swap_list far *) iptr,  /* create point to list */
        if (swap_count > SWAP_LIST_LIMIT)     /* too many data areas */
            return 2;
        /* get pointers and sizes of data areas */
        for (  = 0, i < swap_count, i++)
        {
            swp_list[i].swap_ptr = ptr->swap_ptr;
            swp_list[i].swap_size= ptr->swap_size,
            if (!(swp_save[i] = malloc(swp_list[i].swap_size & 0x7fff)))
                return 3;   /* out of memory */
            if (add_instance_block(swp_save[i],
                    swp_list[i].swap_size & 0x7fff))
                return 4;   /* not instance blocks available */

            swp_flag[i] = 0;
            ptr++;   /* point to next entry in the list */
        }
        return 0;
    }
    else
        return 1;   /* unsupported DOS */
}
/*****
Function: SaveDosSwap
This function will save the dos swap area to a local buffer
It returns ze o on success, non-zero meaning can't swap
*****/
int SaveDosSwap(void)
{
    if (dos_level == 3 || dos_level == 5)
    {
        if (swap_ptr && !dos_critical)
        {
            /* if InDOS flag is zero, use smaller swap size */
            size = (*indos_ptr) ? swap_size_indos : swap_size_always;
            movedata(FP_SEG(swap_ptr),  FP_OFF(swap_ptr),
                     FP_SEG(swap_save), FP_OFF(swap_save),
                     size),

        }
        else       /* can't swap it */
            return 1,
    }
    else if (dos_level == 4)
    {
         /* loop through pointer list and swap appropriate items */
        int i,
        for (i = 0; i < swap_count, i++)
        {
            if (swp_list[ i].swap_size & 0x8000)  /* swap always */
            {
                movedata(FP_SEG(swp_list[i].swap_ptr),
                         FP_OFF(swp_list[i].swap_ptr),
                         FP_SEG(swp_save[i]),
                         FP_OFF(swp_save[i]),
                         swp_list[i].swap_size & 0x7fff);
            }
            else if (*indos_ptr)     /* swap only if dos busy */
            {
                movedata(FP_SEG(swp_list[i].swap_ptr),
                         FP_OFF(swp_list[i].swap_ptr),
                         FP_SEG(swp_save[i]), FP_OFF(swp_save[i]),
```

```
                        swp_list[i].swap_size),
            }
        }
    }
    else
        return 1;
    return 0;
}
/*****
Function: RestoreDosSwap
This function will restore a previously swapped dos
data area
*****/
void RestoreDosSwap(void)
{
    if (dos_level == 3 || dos_level == 5)
    {
        /* make sure its already saved and we have a good ptr */
        if (size && swap_ptr)
        {
            movedata(FP_SEG(swap_save), FP_OFF(swap_save),
                     FP_SEG(swap_ptr), FP_OFF(swap_ptr), size),
            size = 0;
        }
    }
    else if (dos_level == 4)
    {
        int i;
        for (i = 0; i < swap_count; i++)
        {
            movedata(FP_SEG(swap_save[i]), FP_OFF(swap_save[i]),
                     FP_SEG(swp_list[i].swap_ptr),
                     FP_OFF(swp_list[i].swap_ptr),
                     swp_list[i].swap_size),
            swp_flag[i] = 0;    /* clear flag */
        }
    }
}
```

Let's try out the new DOSSWAP method for building TSRs recompile TSRLYAMP.C (Listing 9-15) with DDOSSWAP and then link with the DOSSWAP module (Listing 9-20). See the makefile shown in Listing 9-1.

To use the DOSSWAP method in the multitasking pop-up example presented later we would not want to save not only the foreground data area (data belonging to the process we are interrupting) but the background data area (our TSR's data) as well. The SDA for the TSR could be saved during TSR initialization. Using this method we would not need to deal with DESQview and Extended Error areas at all since they would already exist in the SDA. Always saving and restoring the data area may make it easier to design some sort of round robin task switcher. A hook would step through a table of independent applications (interesting as we saw in chapter 1 the Microsoft Windows 3.x multitasker uses the undocumented SDA function). The "Origins of the SDA" discussion in chapter 8 points out that the SDA is not a genuine DOS internal data structure but merely a portion of DOS's data segment that Microsoft exports for the benefit of networking software and other multitaskers.

If you have examined the actual contents of the DOS SDA in our appendix you can see that this area is quite large. Because of this you may need to weigh the advantages and disadvantages of using the SDA. The primary advantage of using the SDA in TSRs is that you can activate and deactivate at any time while DOS is busy. (Please of course a critical section has been flagged using INT 2Ah). This would be most beneficial for multitasking or round robin task switching since the response to a task switch

must be reinstantiated. In our generic popup TSR for example, using DOSSWAP allows us to pop up instances in the middle of a DIR command.

There are two disadvantages. One is that this function requires memory to save the data areas. This problem could be lessened by swapping the data to extended or expanded memory. Second, this technique is new and its effectiveness has yet to be determined. It's something that you must play with and prove to yourself that it works.

TSRs and Task Managers

A task manager is a resident program which is part of both Windows and DOSSHELL and provides a means to switch between applications or tasks. Both Windows and DOSSHELL allow multiple sessions to be available, giving the user control over which session is active. When writing and using TSRs within a task manager, special consideration must be required for several reasons why.

First we'll provide a little more explanation of how a task manager works in general.

A task manager is an application program that generally presents the user with some type of menu format. One menu item displays what applications can be started, while another menu may display applications that have already been started. It is then up to the user to make a selection with the task manager taking care of activating (and if necessary loading) the chosen application. When an application is deactivated, all information specific to that application is saved or swapped. A simple example would be that all of the application memory is copied and saved to a disk file or extended/expanded memory. When the application is reactivated, the saved information is restored to memory. In reality, the memory swapping is more selective, only storing needed information, such as program data and the MS-DOS swap area. Most times, the swapping is transparent to the application, being activated only as a task.

Okay, enough about task manager operations. What does all this have to do with TSRs?

Most task managers allow multiple DOS COMMAND.COM sessions. Of course, only one session is actively at the foreground at any one moment, but you can switch between sessions.

TSRs are geared to pop up over a single application. However, the foreground application may now be one of many, running in multiple DOS sessions. Because of this, there are two additional areas to watch for in the TSR. The first is that you must treat the TSR in each independent DOS session. Since each session preserves its own memory, one TSR instance would not interact with any other. That does not apply to resources for the TSR, such as each TSR is attached to its own DOS session.

Now, what if you load the TSR after you've started the Task Manager Application? In that case, all DOS sessions have access to a single shared TSR. If the TSR is not reentrant, switching DOS sessions while the TSR is active may cause serious problems. Fortunately, the Windows and DOSSHELL Task Manager provides hooks for TSRs of most basic task creation and switching and also provides what is called instance memory.

Instance memory is a block of memory that is unique for each session. By keeping global data and the stack in this block of memory, each DOS session can have its independent access to the TSR. The TSR provides a list of memory blocks, one for each session, and the Task Manager takes care of keeping the data unique for each session.

Of course, if DOS sessions switch, so does the TSR's data. This is great if you want the TSR to provide communications buffers between the different DOS sessions, but in general this is not how you want a TSR to behave. Consider a resident program loaded before Windows. It has the same data (e.g., the command history buffer) for all. I don't know about declaring instance data, then commands typed in one DOS session will show up when you hit the up arrow key in another DOS session, interesting behavior, certainly, but not what you want. The DOSKEY command line editor, in contrast, knows about instance data. It hooks INT 2Fh, AX=1605h and AX=4810h. As a result, even if DOSKEY is loaded before Windows, commands typed in one DOS session do not leak across to the history buffer seen in the DOS sessions.

The multiplex interrupt (INT 2Fh) is used for communications to and from the task manager. Additional communication structures are also set up through an INT 21h call. Since these functions are documented in MS-DOS technical documentation, I will not go into a lengthy detailed discussion on these items. The January/February 1992 *Microsoft Systems Journal* has an excellent article by Douglas Boling on writing TSRs in an MS-DOS 5.0 environment, which includes details on the task manager API. The Microsoft Developer Network (MSDN) CD-ROM also has an excellent article by David Durgee, "TSR Support in Microsoft Windows Version 3.1." TSR developers, even if they "don't do Windows," must become familiar with these issues. Not to do so will take the control over whether a end user is going to load Windows after loading your TSR.

The following INT 2Fh calls are utilized by our TSR code. These calls are supported by Windows and DOSSETUP.

```
1605h     Windows Start
4801h     Build Notification Chain (attaches TSR to task manager)
4805h     Get Instance Data
```

When the task manager, such as DOSSETUP or Windows 3.1 Standard mode, starts it calls INT 2Fh AX 4801h to build a chain of structures that indicates what programs are interested in receiving session information during session creation and swaps. The task manager also calls INT 2Fh AX 4805h to get information about instance data requested by any programs. The 4805h call is very similar to the Windows INT 2Fh AX 1605h initialization broadcast. Instead, DOSKEY uses the same piece of code to handle both 4805h and 1605h.

As our program processes the INT 2Fh AX 4801h call, it provides the task managers with an address to a structure called SWCALLBACKINFO. This structure provides an address to code that processes all actions messages by the task manager. Before the task manager calls this address, it sets up the appropriate values to pass on to the program. This allows the program to be aware of task states and events such as pending session swaps. If the session switch is a type that can be interrupted, the notification message sent to us is a value that prevents session swaps.

The source code module SWITCHER.C, at Listing 9-21, manages part of the interface to the task manager. The structures were taken right from the MS-DOS programmer's reference. Notice that this is undocumented, but to discuss TSRs without mentioning Windows task switching, and instance data, would be misleading.

Listing 9-21: DOS Task Manager Interface Module SWITCHER.C

```
/* SWITCHER.C -- handles MS task switcher functions */

#include <stdlib.h>
#include <dos.h>
#include <memory.h>
#include "tsr.h"

/* The following structures are defined in the Microsoft "MS-DOS
   Programmer's Reference" for DOS 5 */

/* SWINSTANCEITEM contains information about a block of instance data
   You pass a list of these structure through the SWSTARTUPINFO
   structure.  The list of SWINSTANCEITEM structures is terminated
   by a 32 bit (double word) 0 value. */
typedef struct {
   void  far      *iisPtr,          /* points to instance data */
   unsigned int   iiSize,           /* instance data size */
}  SWINSTANCEITEM,

/* SWSTARTUPINFO Contains information about a client program's instance
   data. Used during an INT 2Fh AX 4805h call */
typedef struct {
   unsigned int   sisVersion,          /* ignored */
```

```
   void far       *sisNextDev,          /* prev. handler's SWSTARTUPINFO */
   void far       *sisVirtDevFile,      /* ignored */
   void far       *sisReferenceData;    /* ignored */
   SWINSTANCEITEM far *sisInstanceData,/* SWINSTACEITEM structures */
}  SWSTARTUPINFO,

 * SWAPIINFO Contains information about the support level a client program
   provides  Since our TSR does not provide any support, this block will
   be set to zeros  Refer to Microsoft's technical reference for more
   details on the values allowed in this structure. */
typedef struct {
   unsigned int   sisLength,            /* size of this structure */
   unsigned int   sisAPI;               /* API identifier */
   unsigned int   sisMajor,             /* major version number */
   unsigned int   sisMinor,             /* minor version number */
   unsigned int   sisSupport;           /* level of support */
}  SWAPIINFO,

 * SWCALLBACKINFO Contains information about the client program */
typedef struct {
   void           far *scbiNext,        /* next SWCALLBACKINFO structure */
   void far       *scbiEntryPoint,      /* notification function handler */
   void far       *Reserved,            /* reserved */
   SWAPIINFO far  *scbiAPI,             /* list of swapping structures */
}  SWCALLBACKINFO,

#define MAX_INSTANCE    20             /* limit to 20 instance blocks */

SWINSTANCEITEM SWInstanceItem[MAX_INSTANCE],  /* instance blocks */
int current_instance = 0,               /* current number of blocks */

SWSTARTUPINFO  SWStartupInfo,
SWAPIINFO      SWSwapInfo,
SWCALLBACKINFO SWCallBackInfo;

int    enhanced_windows = 1,            /* indicating if we're running enhanced mode */
int    switcher_critical = 0,           /* indicating if a switch can happen */

extern union REGS   regs,
extern struct SREGS sregs;

INTVECT switcher_service,

extern  notify_function(),               /* used to get linkage into the supporting ASM
                                            module. We just need the address */

/* the following is from NOTIFY.ASM */
extern void far process_existing_int2f(INTERRUPT_REGS far *r, void far *next);
extern void far check_switcher(void far *ptr);

/* Initialize Switcher Data structures.
   This is where we configure the notification address and any instance
   data that we might need. */
void    init_switcher_structures(void)
{

    /* zero out swap info structure since no API in this TSR support */
    memset(&SWSwapInfo,0, sizeof(SWSwapInfo)),

    /* set address of swap info in the call back structure */
    SWCallBackInfo.scbiAPI = &SWSwapInfo;

    /* set address of notification function handler (in NOTIFY.ASM) */
    SWCallBackInfo.scbiEntryPoint   &notify_function,

    /* zero out instance data structures for now, we'll add some later */
    memset(&SWInstanceItem,0, sizeof(SWINSTANCEITEM) * MAX_INSTANCE);

    /* Set Structure ID */
    SWStartupInfo.sisVersion = 5;
```

```
    /* set up pointers to our instance data */
    SWStartupInfo.sisInstanceData = SWInstanceItem;
}
/* add_instance_block() adds a block to the instance data array.
   This must be called before tsr goes resident
   Returns 0 on success, or 1 if no more instance blocks available. */
int add_instance_block(void far *ptr, unsigned int size)
{
int ret = 0;

    if (current_instance > MAX_INSTANCE-1)
       ret = 1;
    else
    {
       SWInstanceItem[current_instance].iisPtr = ptr;
       SWInstanceItem[current_instance].iiSize = size;
       current_instance++;
    }
    return(ret);
}
/* process_switcher_int2f() checks to see if a switcher command has
   been passed.  If yes, it will process it and return a 0 indicating
   to the caller not to continue with INT 2Fh processing.  A return
   of 1 indicates the caller should process the 2F interrupt. */
int   process_switcher_int2f(INTERRUPT_REGS far *r)
{
    int ret_code;
    segread(&sregs);

    switch (r->ax)          /* see if we're interested */
    {
        case 0x1605          /* windows initialization */
            enhanced_windows = !(r->dx & 1), /* zero in enhanced windows */
            /* call other 2F handlers */
            process_existing_int2f(r, &SWStartupInfo.sisNextDev);
            /* set up saved registers with required address */
            r->es = sregs.ds;
            r->bx = (unsigned int) &SWStartupInfo;
            ret_code = 0;    /* tell caller that all is processed */
            break;
        case 0x4b01:         /* build notification chain */
            /* call other 2F handlers */
            process_existing_int2f(r, &SWCallBackInfo.scbiNext);
            /* set up saved registers with required address */
            r->es = sregs.ds;
            r->bx = (unsigned int) &SWCallBackInfo;
            ret_code = 0,    /* tell caller that all is processed */
            break;
        case 0x4b05:         /* get instance data */
            /* call other 2F handlers */
            process_existing_int2f(r, &SWStartupInfo.sisNextDev);
            /* set up saved registers with required address */
            r->es = sregs.ds;
            r->bx = (unsigned int) &SWStartupInfo;
            ret_code = 0,    /* tell caller that all is processed */
            break;
        default                  /* let every thing else fall through */
```

```
            ret_code = 1;
            break;
        }
    return(ret_code);
}
/* Signal Windows to not task swap */
void windows_begin_critical()
{
    if (enhanced_windows)
    {
        regs.x.ax = 0x1681;
        int86(0x2f, &regs, &regs);
    }
}
/* Signal Windows that task swap ok */
void windows_end_critical()
{
    if (enhanced_windows)
    {
        regs.x.ax = 0x1682;
        int86(0x2f, &regs, &regs);
    }
}
/* See if windows is running in enhanced mode.
   If not, decrement enhanced mode flag */
void check_windows_running(void)
{
    regs.x.ax = 0x1600; /* windows check */
    int86(0x2f, &regs, &regs);
    if (regs.h.al == 0)     /* windows not installed */
        enhanced_windows = 0;
}
/* See if task switcher running (done in assembly) */
void check_switcher_running(void)
{
    check_switcher(ESWCallBackInfo);
}
```

As stated previously, the Task Manager sends messages to your program through a notification call. Since parameters are passed through registers and the notification is not through an interrupt, the ESWCallBack call goes through an assembly language function. That is because you can't control the register usage in C and registers containing parameters are destroyed by C before the program gets a chance to process them. NOTIFY.ASM, in Listing 9-22, manages the rest of the interface to the task manager. The ESWCallBack helper routine checks if the Task Manager is present by calling int2fh function 1684h, then calls the Task Manager int2fh function 1685h to get the address of the Task Manager's int2fh handler. It then passes the int2fh message on to other programs that may be interested in it. The program does not need to preserve any registers after the call to the other int2fh handlers because Borland's C automatically saves register information after the call to the other int2fh handlers. Remember that the documented API usage for the task manager is that the program calls other programs (not a hardware interrupt) of the task manager int2fh function.

Listing 9-22: DOS Task Manager Interface Module NOTIFY.ASM

```
;NOTIFY.ASM

;
; Routines to handle notification messages from the task switcher
; these are not easily (if possible at all) written in C since the
; parameters are passed in registers, and NOT called through an
; interrupt (if they were interrupt functions a C interrupt function
; could handle them. Most of these functions are stubs, returning
; all is ok. The only thing we might want to prevent is switching
; during a TSR critical section, say if we were handling a time
```

```
; sensitive piece of hardware.
;
; None of the notify functions are called from the C program, and should
; not be'
;
;Define segment names used by C
;
_TEXT   segment byte public 'CODE'
_TEXT   ends
CONST   segment word public 'CONST'
CONST   ends
_BSS    segment word public 'BSS'
_BSS    ends
_DATA   segment word public 'DATA'
_DATA   ends
DGROUP  GROUP   CONST,  BSS, _DATA
    assume  CS:_TEXT, DS-DGROUP
    public _notify_function
    public _process_existing_int2f
    public _check_switcher

    extrn  _switcher_service:near     ,switcher service function
    extrn  _switcher_critical:near    ,critical = 1, means no swap'
    extrn  _old_int2f-near             ,original INT 2Fh vector

_TEXT   segment
;*****
;function called by task switcher to notify us of switcher states
;*****
_notify_function proc far
    push    ds
    push    bx
    push    ax
    mov     ax, DGROUP    ;setup to our C data segment
    mov     ds,ax
    pop     ax

;
; save current switcher service function. Documentation says this
; may change, so save every time you get one
;
    mov                                word ptr [_switcher_service], di
    mov                                word ptr [_switcher_service+2], es
;
; setup to call notification function through a jump table defined
; below in data segment
;

    cm                                  pax,7        ;make sure valid function value
    ja      notify_exit
    mov     bx,ax
    shl     bx,1
    call    [SwitcherTable+bx]
notify exit:

    pop     bx
    pop     ds
    ret
```

```
_notify_function endp

;*****
; RET_ZERO used for:
; Function 00 - Initialize Switcher
; Function 03 - Activate Session
; Function 04 - Session Active
; Function 05 - Create Session
; Function 06 - Destroy Session
; Function 07 - Switcher Exiting
;*****
RET_ZERO proc near
    xor     ax,ax       ;signal ok to process
    ret
RET_ZERO endp
;*****
; Function 01 - Query if OK to suspend session
;*****
QuerySuspend proc near
    mov     ax, word ptr _switcher_critical
    ;;; Oops! According to MS-DOS Programmer's Reference for
    ;;; DOS 6 , Task Switcher API Patch,  pp  495-496), under
    ;;; v  5 of the DOS task switcher, the QuerySuspend handler
    ;;; must install a patch that preserves CX.
    ret
QuerySuspend endp
;*****
; Function 02 - Suspend Session
;*****
SuspendSession proc near
    mov     ax, word ptr _switcher_critical
    ret
SuspendSession endp
;Call Old INT 2fh function used to process switcher INT 2fh functions
;from our C code. Its main reason for being is to put
;the INT 2fh registers back to the way when we received the interrupt.
;This is so that the function we call has them in the right place
;
; void process_existing_int2f(INTERRUPT_REGS far *r, void far *next)
;
;*****
_process_existing_int2f proc far
    push    bp
    mov     bp,sp

;
;   Move the original INT 2fh address into the code segment
;   We'll lose the data segment when we reset the registers
;
    mov     ax, word ptr _old_int2f
    mov     word ptr cs:[_save_int2f], ax
    mov     ax, word ptr _old_int2f+2
    mov     word ptr cs:[_save_int2f+2], ax
;
; save address of SWSTARTUPINFO.next
;
    lds     bx, [bp + 10]    ; get address we want to put ES:[BX] into
    mov     cs:tmp_data1, bx ; save address of STRUCTURE
    mov     cs:tmp_data2, ds

;
; get stack back to just after all registers were pushed by the C
; interrupt routine
```

```
;
    lds     bx, [bp+63    ;get pointer to regs structure
    mov     ax, ds
    cli
    mov     ss,ax
    mov     sp, bx
    sti
;
; Restore regs as they were in original INT 2Fh call
;
IFDEF TURBOC
    pop     bp
    pop     di
    pop     si
    pop     ds
    pop     es
    pop     dx
    pop     cx
    pop     bx
    pop     ax
ELSE
    pop     es
    pop     ds
    pop     di
    pop     si
    pop     bp
    pop     bx
    pop     bx
    pop     dx
    pop     cx
    pop     ax
ENDIF
;
; save INT 2Fh function for later compare
;
    mov     cs:tmp_data3, ax ;save request
;
; let others process request
;
    pushf
    call    dword ptr cs:_save_int2f
;
; now update the structure with the address returned in ES:BX
;
    push    ds
    push    ax
    push    bx
    mov     ax,DGROUP ,get data seg so we can store ES:BX
    mov     ds,ax
    pop     ax  ;save value of bx from INT 2Fh call

    mov     bx, cs:tmp_data1 ,get address of structure
    mov     [bx], ax      ;store ES:BX values
    mov     [bx + 2], es
;
; if function 4b01, then structure address is same as next address
;
    cmp     cs:[tmp_data3], 4b01h
    je      skip_dec
    dec     bx ;point to start of structure
```

```
    dec     bx
skip_dec
    push    ds
    pop     es

    pop     ax
    pop     de
    iret
_process_existing_int2f endp

;  *****
; check if task switcher already running.
; If so, setup call back structure to hook notification chain
;  *****
_check_switcher proc far
    push    bp
    mov     bp,sp
    mov     bx,0        ;documentation says must be zeros
    mov     di,0
    mov     es,di
    mov     ax, 4b02h
    int     2fh
    or      al,al
    jns     no_switcher ;none installed, so just exit

;
; save switcher service function
;
    mov     word ptr [_switcher_service], di
    mov     word ptr [_switcher_service+2], es
    les     di, [bp+4]  ;get address of callback structure
    call    dword ptr [_switcher_service]
no_switcher:
    pop     bp
    ret
_check_switcher endp


_save_int2f  dd  0
tmp_data1    dw  0
tmp_data2    dw  0
tmp_data3    dw  0
_TEXT   ends

_DATA   segment
;
; Jump table used to dispatch switcher notification messages
;
SwitcherTable dw offset RET_ZERO      ; InitSwitcher (00)
              dw offset QuerySuspend        ; (01)
              dw offset SuspendSession      ; (02)
              dw offset RET_ZERO      ; ActivateSession (03)
              dw offset RET_ZERO      ; SessionActive (04)
              dw offset RET_ZERO      ; CreateSession (05)
              dw offset RET_ZERO      ; DestroySession (06)
              dw offset RET_ZERO      ; SwitcherExit (07)
_DATA    ends
    end
```

Removing a TSR

Before we get started we would like to extend special thanks to Tim Paterson for all the help he provided in this section for the presentation of *Undocumented DOS*.

There are times when you need to remove a TSR from memory. TSRs use memory and at times conflict with other software. Usually the TSR can be removed so that there is no trace of it ever being installed. The removal process unlinks the TSR from the interrupt vector table and releases all TSR memory back to MS DOS.

One situation that can arise when trying to remove a TSR is that other programs can chain into the same interrupts that the TSR is processing. This prevents you from removing the TSR from the interrupt chain. Consider the following TSR example that chains into interrupt 8.

In this process the code saves the current interrupt address of the TSR's local data storage to be called from inside the TSR. The interrupt vector table now points to the TSR. The following diagram describes the chaining process before and after a TSR adds itself into the chain.

```
Before our TSR loads
INT 08                  > Original Interrupt Service Routine (ISR)
After our TSR is resident:
INT 08 ----------> TSR ISR  --------> Original ISR
```

At this point if you wanted to remove the TSR from the interrupt chain you would just put the original ISR address saved earlier back into the interrupt vector table. The TSR is out of the link. But what if another program has placed itself into the interrupt chain as in the following diagram?

```
INT 08 -----> NEW ISR  -----> TSR ISR -----> Original ISR
```

If you put the value stored for the original ISR back into the interrupt vector table you would be cutting off the new program that has inserted itself into the chain. When it comes time to remove your TSR from the interrupt chain you must check to make sure the interrupt table is pointing to the correct ISR that is *your* interrupt service routine. But is there a way to know that another TSR has been loaded after your TSR? If it isn't, what then?

Currently there are two new strategies that have been discussed for use at retail software. The TSR that has interrupt handlers at the middle of a chain. Several of these tools itself causes a TSR programming no

1. If you can't remove a TSR because there is another application in the chain then at least remove everything possible. Basically restore all vectors to a special ISR that just jumps to the original ISR. On TSR removal deallocate all memory except for the section the special ISR stub uses. This retains the interrupt chain integrity.
2. IBM has proposed a standardized format for interrupt handlers. All handlers will start with a jump instruction followed by data that contains a signature and the original ISR address. The jump will get over the control data block and continue with interrupt processing. This works well with assembly language since you have control over how your ISR appears. This does not translate into C though since a programmer has no control over the structure of the C interrupt function. To achieve this standard in a high level language all interrupts would have to be vectored to code in an assembly routine. The C program would have to restore the original interrupt addresses into the CODE segment of the assembly module. The assembly module would JUMP to the associated C interrupt function. The proposed interrupt structure is shown in Figure 9-23.

Figure 9-23: Proposed Interrupt Chain Structure

```
new_interrupt:      jmp _interrupt_handler
previoushandler     dd 0
signature           dw 4248h        ; "KB"
hardwareflag        db 0
                    jmp hardwarereset
                    db 7 dup (0)  ; Reserved
```

The signature field is an aid for other programs in identifying this interrupt structure. The hardware flag field is important for interrupt handlers that will be issuing an EOI hardware operation. This field should be zero unless the ISR handles a hardware interrupt and is the FIRST installed ISR which becomes the last in the chain. Other handlers are installed. The jump instruction to a hardware reset is a stub that is not needed for software interrupts.

The following code snippet demonstrates how this would be done. Don't forget that the ISR installation section would need to save the old interrupt address in the _old_int8 variable contained in the assembly language routine.

```
public _new_int8, _old_int8
extern _process_int8

_new_int8 proc far
                    jmp far  _process_int8 ;go to C handler
_old_int8           dd 0
signature           dw 4248h
hardwareflag        db 0
                    jmp _hardwarereset ;(if hardware function)
                    db 7 dup (0)  ; Reserved
_hardwarereset:
                    retf ;just return in case someone calls into this label
_old_int8
 new_int8 endp
```

The interrupt handler in C would look like it always does.

```
void interrupt far process_int8(INTERRUPT_REGS z)
{
     // interrupt processing
     _chain_intr(_old_int8)
}
```

Note: this is only a proposed standard; our sample ISR does not include such code, but it probably should.

The generic ISR developed in this chapter can be removed by a command line argument. If you have previously loaded ISRTEST.EXE, the command ISRTEST -U unloads the resident copy of ISRTEST.EXE. The -U tells the generic ISR shell to signal its resident ISR program to unload and not to load up another copy.

The generic ISR uses INT 2Fh to communicate between the newly executed copy and the resident copy. The actual function number AH can be set with a command line parameter, but the subfunctions in AL are hardcoded into the ISR program. A value of zero in the AL register is an install check, and it also returns a deinstall command. The use of zero for the install check is dictated by the standard Multiplex Interrupt interface.

The following steps are required for deinstalling. These steps follow the INT 2Fh deinstallation call. Step one must be performed by the ISR since only it knows what addresses to restore to the interrupt vector table. Steps two through five can be performed either by the ISR or the calling application.

1 Set all of the interrupt vectors the TSR has changed to point to the interrupt service routines. Restore all vectors that have not changed since the TSR changed into them. If any interrupt vectors were changed, disable the TSR operations and skip the following steps to leave the TSR in memory.
2 Set the parent PSP of the TSR to be that of the application that executes the INT 21h deinstallation call. The parent PSP value is contained at offset 16h of the TSR's PSP.
3 To return control to the calling application, set the termination address to be a location in the calling application.
4 Set the current PSP to the PSP of the TSR. Doing this allows DOS to free the TSR's memory and close any open files.
5 Execute the normal DOS terminate function (INT 21h Function 4Ch). When the TSR has been terminated by DOS, control returns to the terminate address set in step three.
6 At this point, all registers have unknown values. The calling process must save them before issuing the INT 21h deinstallation command. They can now be restored.

If the TSR is not performing steps two through five, it must return its PSP value as part of the INT 21h interface.

The generic TSR performs steps one through five. TSRU.ASM contains the deinstallation call through INT 21h, and TSRUTSR.ASM contains the rest of the code that handles deinstallation. The pseudocode in Figure 9-24 describes the generic TSR's operation.

Figure 9-24: Generic TSR Unload Pseudocode

```
Foreground Application          Resident Application (TSR)

Save SI, DI, BP, SS and SP registers
Set AX=C001h
Set BX:DS to terminate address (TERM_ADDR,
   used in step 3 above)
Perform INT 2Fh
                                TSR receives INT 2Fh request
                                Set up local stack
                                Attempt to unlink interrupts
                                If unable to unlink all
                                  interrupt vectors, then:
                                      Set AL = 0xFF
                                      Return from INT 2Fh
If we get here, the deinstallation failed
Check AL register and display proper message
EXIT
                                Get PSP (foreground app.)
                                Set parent PSP field in our PSP
                                Set terminate address in our PSP
                                   to address passed via INT 2Fh
                                Set PSP to TSR's PSP
                                Call MS-DOS terminate
TERM_ADDR
Restore SI, DI, BP, SS and SP registers
EXIT
```

Many times a TSR is not able to deinstall due to interrupt vectors changed by another application. A return from the INT 2Fh call with AL = 0FFh indicates that the TSR could not unhook itself from one or more interrupts. Deinstalation also fails if the TSR is not installed to begin with. This is indicated by AL = 0Ah on return from the INT 2Fh call.

Sample TSR Programs

To exercise the generic TSR, we built three different simple TSRs, two of which are pop-up versions of programs from other parts of this book.

TSRFILE

The first sample program, TSRFILE (see Listing 9-25), demonstrates that you really can make DOS function 0Ah and memory allocation calls while you're popped up in the middle of some other program. When TSRFILE pops up, it prompts the user for a filename and then displays the file on the screen. No screen saving/restoring amenities are provided.

FILE.C uses the Microsoft C _dos functions for the I/O and memory allocation. These functions translate directly into the appropriate INT 21h calls and are thus preferable to using the intdos or intdosx functions. Instructions for creating FILE.C and TSRFILE.EXE are found in the makefile shown in Listing 9-1. It can also be compiled as a.c and runs FILE.EXE.

Listing 9-25: Example Pop-up FILE.C

```
/* FILE.C */

#include <dos.h>
#include <conio.h>
#include <fcntl.h>
#include <share.h>

char file_prompt[] = "File? ",
char cant_open[] = "Can't open file\r\n",
char error_reading[] = "Error reading file\r\n";
char insuff_mem[]    "Insuffic ent memory, Press any key...\r\n";
char crlf[]    \r\n",

#define PUTSTR(s)   \
    dos_write(STDERR, (char far *) s, strlen(s)-1, &wcount)

#define MIN_PARAS   4
#define WANT_PARAS  64
#define BYTES       (paras << 4)

#define STDERR      2

#ifdef TSR
void application(void)
#else
main(void)
#endif
{
    char buf[81];
    char far *s,
    unsigned rcount, wcount, ret, paras, seg,
    int f,

    /* prompt for filename */
    if (PUTSTR(file_prompt) != 0)
        return,

    /* get filename */
    if (( dos_read(STDERR, buf, 80, &rcount) !  0  || (rcount < 3))
        return,
    /* replace CRLF with NULL */
    buf[rcount-2] = '\0';

    /* try to allocate: first try a lot, then a little */
    if (_dos_allocmem(WANT_PARAS, &seg) == 0)
        paras = WANT_PARAS,
    else if ( dos_allocmem(MIN_PARAS, &seg)    0)
        paras = MIN_PARAS;
    else
```

```
    {
        PUTSTR(insuff_mem);
        return;
    }
    FP_SEG(s) = seg;
    FP_OFF(s) = 0;
    /* open file */
    if (_dos_open(buf, O_RDWR | SH_DENYNO, &f) != 0)
        return PUTSTR(cant_open);
    /* display file */
    while (( ret   _dos_read(f, s, BYTES, &rcount)) == 0) && rcount)
        if (_dos_write(STDERR, s, rcount, &wcount) != 0)
            break;
    /* write one more CRLF */
    PUTSTR(crlf);
    if (ret)
        PUTSTR(error_reading);
    /* free memory */
    _dos_freemem(seg);
    /* close file */
    _dos_close(f);
    PUTSTR("Press any key...");
}
```

HELP C makes two stabs at allocating memory because, at page up over COMMAND.COM there is almost no free memory available. COMMAND owns the largest block in memory, and all that are left are little drabs and dabs like the environment we freed during TSR initialization. You can see this situation when running our second example, the MEM program as a TSR.

TSRMEM

One problem with the MEM program presented in Chapter 7 was that since it was a standalone program, you could only examine the memory map from within MEM itself. By putting the generic TSR and MEM together to form TSRMEM.EXE, you can examine the memory map with other programs. For example, you can clearly see how COMMAND grabs the largest chunk of memory, leaving almost nothing free.

```
C:\UNDOC2\CHAP9>tsrfree
C:\UNDOC2\CHAP9>tsrmem -k 59 8 -f 1
C:\UNDOC2\CHAP9>\sidekick\sk

[Hit TSRMEM hotkey, Alt-F1]
Seg     Owner   Size
09F3    0008    00F4 (  3904)   config [35 40 67 ]
0AE8    0AE9    0D03 (  3376)   0BC0 c:\dos33\command.com  [22 2E ]
0BBC    0000    0003 (    48)   free
0BC0    0AE9    0019 (   400)
0BDA    171A    0000 (   208)
0BE8    0000    0000 (     0)   free
0BE9    0BEA    0575 ( 22352)            [F1 FA ]
515F    1160    0589 ( 23440)    -k 59 8 -f 1 [1B 23 24 2F F4 F5 ]
1719    171A    1985 (105296)   0BD0 C:\SIDEKICK\SK.COM  [08 09 10 13
                                        16 1C 21 25 26 28 ]
3DCF    0AE9    8730 (553728)           [30 F8 ]
```

The largest block in the MCB chain totaling 8730h paragraphs is not marked "free." Instead, it's owned by PSP 0AE9. Looking back along the MCB chain, which associations as a PSP chain, you can see that 0AE9 is COMMAND.COM. In fact, there are only three paragraphs of free memory located directly after COMMAND. Even the environment TSRMEM freed was picked up by Side

kick for use as its environment. If you hot-load SRUNTIME's hotkey (Alt-D) at this point, it will ask for the filename and then report "Insufficient memory."

However, if you leave COMMAND by running an application and then hitting Alt-D, there is actually plenty of memory because COMMAND is no longer hogging the largest block. Again, this shows precisely why you hot-load SRUNTIME's hotkey within some other application. The MCB belonging to COMMAND.COM has now been replaced by the following:

```
30CF    300E    0000 (    208)
3000    300E    292D (168656)   3000 c:\eps\EPSILON.EXE  [00 05 16 ]
5A0B    0000    5DF4 (384832)   free    [30 F8 ]
```

Since DOS reports 5DF4 paragraphs of free memory, you now have no trouble allocating memory in SRUNTIME.

Porting MEMLIB to test the generic TSR was straightforward. We had to get rid of a call to calloc(), replace any calls to exit() with simple returns, expand any '\n' characters into "\r\n", and make a few other minor adjustments. The key change, however, was to link with a version of printf() that doesn't use malloc(). Because, after initialization, the TSR would have no near heap from which to allocate memory.

This non-malloc version of printf() is provided in the module PUT.C, which can be used with any program that uses the generic TSR. The non-malloc version of printf() uses the stdarg facilities of ANSI C, so you can use the function to create functions that take variable argument lists. PUT.C also contains a number of other helpful functions. Prototypes for the functions appear naturally in PUT.H (see Listing 9-26).

Listing 9-26: No-malloc STDERR Output: PUT.H

```
/* PUT.H -- STDERR output routines, no malloc */

// calls _dos_write, returns number of bytes actually written
unsigned doswrite(int handle, char far *s, unsigned len);

// displays ASCIIZ string on STDERR
unsigned put_str(char far *s);

// displays character on STDERR
unsigned put_chr(int c);

// displays number (width, radix) on STDERR
unsigned put_num(unsigned long u, unsigned wid, unsigned radix);

// PUT.C includes alternate version of printf(), goes to STDERR,
// don't use malloc(). Same prototype as <stdio.h>

// get str[] from STDERR, returns actual length
unsigned get_str(char far *s, unsigned len);

#define putstr(s)       { put_str(s); put_str("\r\n"); }
#define put_hex(u)      put_num(u, 4, 16)
#define put_long(ul)    put_num(ul, 9, 10)
```

In MEMLIB, the C preprocessor #ifdef statement was used to conditionally compile either a stand-alone or a TSR version. For example:

```
#ifdef TSR
void fail(char *s) { printf("%s\r\n", s); return; }
#else
void fail(char *s) { puts(s); exit(1); }
#endif
```

The changes needed to make MEM a pop up were all of a similar nature and are so straightforward and uninteresting that we leave them as an exercise for the reader. In any case, the existing TSRMEM.EXE can be found on the disk that accompanies this book.

TSR2E

Finally, we pump the gun a little bit by porting a program from the next chapter in this book. As Jim Kyle will explain, INT 21h is the backdoor to the DOS command interpreter. The TEST2E command interpreter from Chapter 10 can be easily turned into a TSR to provide an instant pop up copy of COMMAND.COM.

This really does work. The only peculiarity is that on occasion when you pop up TSR2E and type in a command, the following message appears from the resident portion of COMMAND.COM:

```
Memory allocation error
Cannot start COMMAND, exiting
```

Note, however, that this is different from the horrifying message one sees when the MCB chain has been trashed:

```
Memory allocation error
Cannot load COMMAND, system halted
```

The message "exiting" rather than "system halted" is the key. If you try to execute the command again it works. In any case, you should probably use the list of other INT 21h calls found in the next chapter.

You can use TSR2E not only to execute internal commands such as DIR or COPY, but also to execute external commands that are in other programs or even batch files.

As shown in the models presented earlier in the chapter, you build TSR2E by converting the generic TSR components with Jim Kyle's source files SEND2E.C, TSRXAMP.C, TSR12.ASM and DOS2E.ASM. These files are unchanged. All changes for a pop up TSR are confined to the module TEST2E.C, where we change the name of the module and put in the main loop to application code and add a test that sets TSR2E as the pop up when COMMAND.COM is ready to run, and use the facilities of the PSP's environment pointer (see Chapter 6, Standard Library malloc() and free() routines). The altered version of TEST2E.C appears in Listing 9-27.

Listing 9-27: Example Pop-up TEST2E.C

```
#include <stdlib.h>
#include <string.h>
#include <dos.h>

#include "put.h"

#define MK_FP(seg,ofs) \
    ((void far *)(((unsigned long)(seg) << 16) | (ofs)))

extern unsigned *foreground_psp;      // in TSRXAMP.C
extern int Send2E(char *command);     // in SEND2E.C

static char buf[80];
static int running = 0;

typedef enum { SAVE=0, RESTORE } SAVEREST;
typedef void (interrupt far *INTVECT)();

void interrupts(int restore)
{
    static INTVECT int_1b, int_23, int_24;
    if (restore)
    {
        _dos_setvect(0x1b, int_1b);
        _dos_setvect(0x23, int_23);
        _dos_setvect(0x24, int_24);
```

```
    }
    else
    {
        int_1b = _dos_getvect(0x1b);
        int_23 = _dos_getvect(0x23);
        int_24 = _dos_getvect(0x24);
    }
}
void application(void)
{
    // don't run if we are already running
    if (running)
        return;
    running++;
    // don't execute INT 2Eh if COMMAND.COM already running
    // see if COMMAND.COM running by checking if current PSP is the
    // same as its own parent (see chapter 10)
    if (foreground_psp ==
        *((unsigned far *) MK_FP(foreground_psp, 0x16)))
    {
        put_str("COMMAND.COM already running");
        running--;
        return;
    }
    put_str("TSR COMMAND SHELL. type DOS commands,    or BYE to quit\r\n");
    for(;;)
    {
        put_str("$ ");
        if (! get_str(buf, 80))
            break;
        if (strcmp(buf, "bye") == 0 ||  strcmp(buf,    "BYE") == 0)
            break;
        interrupts(SAVE);
        Send2E(buf);
        interrupts(RESTORE);
    }
    putstr("Bye ");
    running--;
}
```

We save and restore the Ctrl C, Ctrl Break, and Critical Error interrupts around the call to Send2Eh(). With this precaution, even Ctrl C, Ctrl Break, and Critical Errors are handled properly within the INT 2Fh pop up.

```
TSR COMMAND SHELL  type DOS commands, or BYE to quit
$ dir a

Not ready error reading drive A
Abort, Retry, Fail? a

$ dir *.c /w

 Volume in drive C is RAMANUJAN
 Directory of  C:\UNDOC\RMICHELS

DOSSWAP  C      EXTERR   C      ^C

$ bye
Bye
```

One word about trying to install a TSR from within the pop up command interpreter: DON'T! This will hang your system sometime after you exit the pop up.

Multitasking TSR

Finally let us discuss TSRs that don't pop up at a user hotkey but which do their work in the background. We call such programs multitasking TSRs to distinguish them from pop-ups. MULTI.EXE is a multitasking TSR shell that can be modified to perform multiple background tasks from disk file copying to background communications.

The example presented here is an enhancement to the DOS PRINT utility. It periodically activated by INT 8 and INT 28h, searches a SPOOL directory for files having the extension SPL. When it finds a match the TSR uses PRINT's INT 2Fh function 01h interface to ask PRINT to print the file. Once the file has been submitted for printing the TSR periodically obtains status report from PRINT. If the file is no longer in the print queue, its printing is complete, the file is deleted.

```
C:\UNDOC2\CHAP9> print
C:\UNDOC2\CHAP9> multi
C:\UNDOC2\CHAP9> copy \undoc\rmichels\*.asm \spool\*.spl
C:\UNDOC2\CHAP9> dir \spool
 Volume in drive C is RAMANUJAN
 Directory of  C:\SPOOL

.            <DIR>       3-23-89   9:54p
..           <DIR>       3-23-89   9:54p
TSRUTIL  SPL     5852    9-17-90  11:40p
STACK    SPL     1758    9-17-90  11:36p
       4 File(s)     96208 bytes free

C:\UNDOC2\CHAP9> print

     C:\SPOOL\TSRUTIL.SPL is currently being printed

C:\UNDOC2\CHAP9> dir \spool
 Volume in drive C is RAMANUJAN
 Directory of  C:\SPOOL

.            <DIR>       3-23-89   9:54p
..           <DIR>       3-23-89   9:54p
STACK    SPL     1758    9-17-90  11:36p
       3 File(s)    102400 bytes free
```

Basically the program manages two independent processes: the foreground process and the background process. When a user hotkey process is started, the current process is suspended. Foreground registers are saved on the stack for later restart. Once the TSR has been asked to terminate, the environment of the suspended process is restored and the registers are restored.

This multitasking is achieved by marking time slices based on the timer tick rate. Each process gets a specific amount of time. In the preceding example, the foreground process gets the most time so as not to degrade performance. It is possible to add more tasks, but one would need to maintain a list of SS:SP sets to service all running processes.

Most of the code is similar to INSTALL.ASM. The two main differences are that activation is through INT 8 (the timer interrupt) and not hotkey, and that instead of completing its work during activation the TSR is suspended for later restart. Because DOS is not reentrant, the TSR still must follow the rule of not interrupting DOS when it is active.

In most computer systems, multitasking is a method of quickly switching from one task to another so that the computer appears to be running multiple tasks at the same time. Of course, it is not as simple as that. Multitasking systems are designed so that resources such as disks, screens, and keyboards can be shared by multiple applications. Even most multitasking systems such as OS/2 supply interface routines that are reentrant. The code segment of each routine is stored only once in memory, and this code segment can be started by multiple processes at the same time. Each user gets his or her own instance of data. But as we know, the INT 21h API is not. Only so much multitasking example is controlled to some extent by the DOS flags.

Task Switching

Every process has what can be called its context or frame. This consists of the following items:

- Register values, including code, data, and stack segment values
- Program Segment Prefix (PSP) or process ID
- Disk Transfer Address
- Extended Error Information

To stop a task or context switch, these items must be saved and replaced by ones that pertain to the new task. The example simply flips between two tasks. If more independent tasks were required, we would have to keep a list of information about each task. Each item in the list might contain the relevant DOS information, INT 2Fh AX=1220h, and a pointer to the process stack segment and offset. You might also want to keep and switch between copies of the SDA for each task. The code to perform the list management is more complex and is not presented here.

The type of multitasking presented here is called time sharing because each task gets a predetermined slice of time to run. It needed, more intelligence could be added that would control how much time each process gets. This could be based on usage of the operating system (INT 28h or Idle Task INT 2Fh). You could detect those interrupts and if a process is making extensive use of those resources, you could lower its time slice to give other processes more time.

Here's what's going on during the background process. When the file being printed is still in the print queue, a memory variable is set so that background processing terminates immediately. There's no point in running in the background. The program is simply waiting for the print spooler to complete its job.

One word regarding the use of MULTI with other task switchers: DOS 5+. Things can get very confusing with two copies of top of multitasks. MULTI is not compatible with Microsoft Windows. Even with Windows, MULTI intercepts the Windows startup message: INT 2Fh AX=1605h and changes the value returned in the CX register. This tells Windows to abort its startup.

MULTI Installation

MULTI uses existing DOS techniques already described. Some interrupt handling routines must be installed to segment the normal interrupt process. On returning from most interrupts, the flags are restored to their condition just before the interrupt was invoked. But three of the interrupts we are interested in handling, INT 23h, 24h, and 26h, do not follow this convention. INT 23h, Ctrl-Break, INT 24h, errors or conditions such as Ignore, and INT 13h handler must end with a RETF 2 rather than a RET. Meanwhile, the DOS disk-access routines, INT 25h and 26h, leave the flags on the stack, so they, too, must execute a RETF rather than an IRET. This code is marked as HDDF MULTI.ASM, SET_INT_VECTOR, where carry = 1 means use RETF.

Another difference between [SRI]VAMP and MULTI is that in MULTI, the address of the task stack is the address of the stack that is created on the main procedure. This is typical of [illegible] to start at this address when the background process is first activated.

Timer Interrupt

MULTI is activated [illegible] by the INT 8 timer tick interrupt. MULTI's INT 8 handler [illegible] which keeps track of how many timer ticks have occurred. Each process that [illegible] is allowed a given number of ticks. Once the current tick count exceeds the process limit, [illegible] DOS is zero except within INT 28h, in which it will be one, but must not be more than one [illegible]. Then it JMPs FAR that process suspends and the other process activates.

At this point, you can suspend the process. Depending on what process you are currently executing, you can call either suspend background or suspend foreground. To suspend the foreground, set the

stack to be the local TSR stack. In either case, it carries out the save-context operation to save the registers used earlier in the function at TSRIVARS setting INT 1Bh, 23h, and 24h and swapping PSP, DTA, and extended error information.

On returning to the new TSR function, it restores the stack from the context and activates the foreground process and passes control along the INT 8 interrupt chain.

One special condition applies the first time you activate the background process. At this point, you have never interrupted this process, so its registers are not on the stack. Because of this, an assembly language function must create a stack frame to pass control into a task handler.

We earlier referred to a flag variable called unsafe flag. Since there is no INT 28h flag to use, you have to create your own. unsafe flag is set TRUE when critical BIOS services, INT 10h, video, and INT 13h, disk, or the DOS absolute disk services, INT 25h and 26h, are in progress.

Idle Interrupt

The timer interrupt is not the only way you can run in the background. You also use the DOS idle interrupt, INT 28h, discussed earlier. This allows you to do background processing while the system is sitting at the COMMAND prompt. Otherwise, you would never run in the background while COMMAND was awaiting orders.

During an INT 28h, if the Int28Hook function returns FALSE and the background is not already active, you set the background task to zero and the int 28 active variable to TRUE. Then wait for the int 28 active variable to go FALSE before continuing. This allows a nearly immediate task switch to the background process.

Keyboard Interrupt

Notice that we have installed a service routine for INT 9, the keyboard hardware interrupt. When ever the user presses a key, the background task time-out is set to zero, causing the task to go into a suspended state more quickly. This gives the user better response time.

Printing

The main loop function in our example is the background process. This function performs the work of searching for files and submitting them to the spooler using INT 21h, Function 0Fh. Notice that this example includes a nested loop that does nothing during the main loop operation. This is to avoid constant disk access by the background task. The background time count is also set to zero in a number of places to ensure that the background process stays suspended for that time.

MULTI.C

Listing 9-28 shows MULTI.C, the source code for the multitasking TSR. To build MULTI.EXE, use the instructions found in the makefile at Listing 9-1.

Listing 9-28: MULTI.C

```
/* MULTI.C */
#include <stddef.h>
#include <stdlib.h>
#include <stdio.h>
#include <string.h>
#include <dos.h>
#include <io.h>
#include "tsr.h"
#include "put.h"

#define SEARCH_DIR   "C:\\SPOOL\\*"
#define STACK_SIZE   4096   /* must be 16 byte boundary */
#define SET_DTA      0x1a   /* SET Disk Transfer Address */
#define GET_DTA      0x2f   /* GET Disk Transfer Address */
```

```
#define BACKGROUND_TICKS 2
#define FOREGROUND_TICKS 16
#define BACKGROUND_YIELD 0
#define FOREGROUND_YIELD 0

struct  prReq
{
    char level;
    char far *fname;
},
char    far *stack_ptr;   /* stack for our background TSR */
char    far *ptr,
unsigned ss_save,         /* slot for stack segment register */
unsigned sp_save,         /* slot for stack pointer register */
unsigned unsafe_flag = 0; /* set true by various interrupts */
 nt first_time = 1,       /* flag for first time in running background */

int my_psp;               /* our TSR's psp */
int foreground_psp,       /* PSP of interrupted foreground process */
int foreground_dta_seg,   /* DTA of interrupted foreground process */
int foregr und_dta_off,
int ctr=0,
int tic_count = 0;        /* counts timer tices */
int in_progress = 0,      /* true if we're in background process */
int breakState,           /* Extended Break Status of foreGround */
 nt dos_count   0,        /* count of our calls into DOS */
int multi_critical = 0;   /* indicates we can't swap right now */
char search_work[65],
struct ExtErr my_ErrInfo;
struct ExtErr foreground_ErrInfo;

int foreground_limit = FOREGROUND_TICKS, /* foreground cycle limit */
int background_limit = BACKGROUND_TICKS, /* background cycle limit */

char search_dir[65] = {SEARCH_DIR}, /* dir to search for spool files */
volatile int   int_28_active   0,   /* true if activated by INT 28h */
volatile int   interva_timer,       /* for sleeping a number of ticks */

/* old interrupt pointers are stored here */
INTVECT old_int8, old_int9, old_int10, old_int13,
INTVECT old_int1B, old_int21, old_int23, old_int24, old_int25,
INTVECT old_int26, old_int28, old_int2f,

/* prototypes for this module */
void main_loop();
void interrupt far new_int8(INTERRUPT_REGS),
void interrupt far new_int9(INTERRUPT_REGS),
void interrupt far new_int10(void);
void interrupt far new_int13(void),
void interrupt far new_int1B(INTERRUPT_REGS),
void interrupt far new_int21(INTERRUPT_REGS ,
void interrupt far new_int23(INTERRUPT_REGS),
void interrupt far new_int24(INTERRUPT_REGS),
void interrupt far new_int25(void),
void interrupt far new_int26(void);
void interrupt far new_int28(INTERRUPT_REGS),
void  nterrupt far new_int2f INTERRUPT_REGS),
int  spooler_active(void);
int  search_spl_que(char * fname);
void suspend_foreground(void);
void suspend_background(void);

/* returns nonzero if PRINT installed */
int spooler_active()
{
    union REGS  regs;

    regs.x.ax = 0x0100;         /* PRINT install check */
    int86(0x2f,&regs,&regs);    /* call multiplex interrupt */
```

```
    return(regs.h.al == 0xff);  /* FF if installed */
}
/* returns nonzero if file is in the spooler queue  */
int search_spl_que(char * fname)
{
    union REGS  regs,
    struct SREGS   sregs;
    char far *  que_ptr,
    char que_name[65];
    int i;
    int found = 0;
    if (spooler_active())
    {
        regs.x.ax = 0x0104,  /* get spooler status */
        int86x(0x2f,&regs,&regs,&sregs);
        /* on return from call DS:SI points to print  queue */
        FP_SEG(que_ptr)   = sregs.ds,
        FP_OFF(que_ptr) = regs.x.si,
        /* release hold on spooler, side effect of status*/
        regs.x.ax = 0x0105,
        int86x(0x2f,&regs,&regs,&sregs),
        while (*que_ptr && !found)  /* while items in queue */
        {
            for (i = 0; i < 64; i++)
                que_name[i] = *(que_ptr + i);
            if (found = !strcmpi(que_name,fname))
                break;
            que_ptr += 64;
        }
    }
    return(found),
}
void main_loop()
{
    struct find_t c_file,
    union REGS regs;
    struct SREGS sregs,
    struct prReq prRequest;
    struct prReq far * ptr;
    int sleep_cntr;
    while (1)
    {
        strcpy(search_work,search_dir),
        strcat(search_work,"*.SPL"),   /* create dir  search string */
        interval_timer = 18 * 30,      /* search every 30 seconds */
        while (interval_timer)     /* wait between each dir search */
            background_limit   BACKGROUND_YIELD,  /*  yield for fgrnd */
        if (!_dos_findfirst(search_work,_A_NORMAL,&c_file))
        {
            /* if spooler installed, dos 3.xx+ and file size > 0 */
            if (spooler_active() && _osmajor >= 3 && c_file.size)
            {
                strcpy(search_work,search_dir),
                strcat(search_work,c_file.name); /* full pathname */
                prRequest.level = 0,
                prRequest.fname = search_work;
                regs.x.ax = 0x0101,
                ptr = &prRequest,
                sregs.ds = FP_SEG(ptr);
                regs.x.dx= FP_OFF(ptr);
                int86x(0x2f,&regs,&regs,&sregs),
```

```
                while (search_spl_que(search_work))  /*  wait till done */
                {
                    interval_timer = 18 * 30;  /* sleep  for 30 seconds */
                    while (interval_timer)
                        background_limit = BACKGROUND_YIELD;
                }
                unlink(search_work);     /* delete file */
                background_limit = BACKGROUND_YIELD;
            }
        }
    }
}

union REGS regs;
struct SREGS sregs;

void suspend_foreground()
{
    /* save current extended break status */
    breakState = GetBreak();

    /* set extended break status to be off */
    SetBreak(0);

    /* SWAP TO BACKGROUND */
    tic_count = 0;
    /* save old handlers */
    old_int1B = _dos_getvect(0x1B);
    old_int23 = _dos_getvect(0x23);
    old_int24 = _dos_getvect(0x24);

    /* set our interrupt handlers */
    _dos_setvect(0x1b,new_int1B);
    _dos_setvect(0x23,new_int23);
    _dos_setvect(0x24,new_int24);

    /* save current PSP and set to ours */
    foreground_psp = GetPSP();
    SetPSP(my_psp);

    /* get foreground DTA */
    regs.h.ah = GET_DTA;
    intdosx(&regs, &regs, &sregs);
    foreground_dta_seg = sregs.es;
    foreground_dta_off = regs.x.bx;

    /* set up our DTA */
    regs.h.ah = SET_DTA;
    regs.x.dx = 0x80;   /* use default in PSP area  */
    sregs.ds = my_psp;
    intdosx(&regs, &regs, &sregs);

    /* save error info */
    GetExtErr(&foreground_ErrInfo);

    if (! first_time)
        SetExtErr(&my_ErrInfo);

    in_progress = 1;
    background_limit = BACKGROUND_TICKS; /* set default limit */
}

void suspend_background()
{
    /* SWAP TO FOREGROUND */

    /* put back original DTA */
    regs.h.ah = SET_DTA;
    regs.x.dx = foreground_dta_off;
    sregs.ds  = foreground_dta_seg;
    intdosx(&regs, &regs, &sregs);
```

```
    /* put back original PSP */
    SetPSP(foreground_psp);
    /* put back original INTS */
    _dos_setvect(0x1b,old_int1B);
    _dos_setvect(0x23,old_int23);
    _dos_setvect(0x24,old_int24);
    /* get error info */
    GetExtErr(&my_ErrInfo);
    SetExtErr(&foreground_ErrInfo);
    tic_count = 0;
    in_progress = 0;
    int_28_active = 0;
    foreground_limit = FOREGROUND_TICKS; /* set default limit */
    /* put back extended break checking the way it was */
    SetBreak(breakState);
}
/**********
* TIMER TICK INTERRUPT HANDLER
**********/
void interrupt far new_int8(INTERRUPT_REGS r)
{
    _enable();              /* enable interrupts */
    tic_count++;
    if (interval_timer)
        interval_timer--;

    if (in_progress &&
        !mult critical &&
        dos_count == 0 &&
        ((tic_count >= background_limit &&
            !DosBusy() && !unsafe_flag) ||
        (int_28_active && !Int28DosBusy() &&
            tic_count >=background_limit)))
    {
        suspend_background();
        restore_stack();
    }
    else if (!in_progress &&
            ((tic_count >= foreground_limit &&
                !DosBusy() && !unsafe_flag) ||
            (int_28_active && !Int28DosBusy() &&
                tic_count >=foreground_limit)))
    {
        set_stack();
        suspend_foreground();
        if (first_time)
        {
            first_time = 0;
            timer_int_chain();
        }
    }
    old_int8();    /* call old handler */
}
/**********
* KEYBOARD INTERRUPT HANDLER
**********/
void interrupt far new_int9(INTERRUPT_REGS r)
{
   unsafe_flag++;
   old_int9();
```

```
    if (in_progress)
      background_limit = BACKGROUND_YIELD; /* set to swap to fgrnd */
    foreground_limit = 18,                 /* since user hit keyboard */
    unsafe_flag--,
}

/*********
* CTRL-BREAK INTERRUPT HANDLER
*********/
void interrupt far new_int1B(INTERRUPT_REGS r) { /* do nothing */ }

/**********
* CTRL-C INTERRUPT HANDLER
**********/
void interrupt far new_int23(INTERRUPT_REGS r) { /* do nothing */ }
/**********
* CRITICAL ERROR INTERRUPT HANDLER
**********/
void interrupt far new_int24 (INTERRUPT_REGS r)
{
    if (_osmajor >= 3)
        r.ax = 3;   /* fail dos function */
    else
        r.ax = 0,
}
/**********
* DOS IDLE INTERRUPT HANDLER
**********/
void interrupt far new_int28(INTERRUPT_REGS r)
{
    if (!in_progress && *Int28DosBusy() && !unsafe_flag &&
        tic_count > foreground_limit)
    {
      foreground_limit = FOREGROUND_YIELD,   /* stop foreground */
      int_28_active = 1;
      _enable(),                /* STI */
      while (int_28_active)
          ;         /*spin waiting for task swap to  bckgrnd*/
    }
    (*old_int28)();    /* call old handler */
}
/**********
* DOS MULTIPLEX INTERRUPT HANDLER
**********/
void  interrupt far new_int2f(INTERRUPT_REGS r)
{
    /* See  if windows is starting up  If so, then set CX to be non-zero
       to keep windows from starting  this TSR and Windows are not
       compatible. */
    if (r.ax == 0x1605) /* windows init msg */
        r.cx   1,
    else
        chain_intr(old_int2f), /* pass int to other handlers */
}
main()
{
    unsigned        memtop, dummy,
    void far* far*  tmpptr,
    puts("Multi-Tasking PRINT spooler installing ),
    if (_osmajor < 3)
    {
        puts("Error: MS-DOS version 3.00 or greater required");
```

```
        exit(1);
    }
    if (! spooler_active())
        puts("Warning: Print Spooler not active"),

    InitInDos(),
    my_psp = GetPSP();

    /* MALLOC a stack for our TSR section */
    stack_ptr = malloc(STACK_SIZE);
    stack_ptr += STACK_SIZE;
    ptr = stack_ptr;
    *(--stack_ptr) = 0xf2,  /* set up stack as if an an IRET was done*/
    *(--stack_ptr) = 0x02;
    stack_ptr -= 4,
    tmpptr = stack_ptr;
    *(tmpptr) = main_loop;

    /* get interrupt vectors */
    old_int8  = _dos_getvect(0x08), /* timer int */
    old_int9  = _dos_getvect(0x09); /* keyboard int */
    old_int10 = _dos_getvect(0x10), /* video int */
    old_int13 = _dos_getvect(0x13), /* disk int */
    old_int21 = _dos_getvect(0x21); /* dos int */
    old_int25   _dos_getvect(0x25), /* sector read  int */
    old_int26 = _dos_getvect(0x26), /* sector write int */
    old_int28 = _dos_getvect(0x28), /* dos idle int */
    old_int2f   _dos_getvect(0x2f), /* dos multiplex int */

    init_intr(),    /* init asm variables */

    _dos_setvect(0x08,new_int8),
    _dos_setvect(0x09,new_int9),
    _dos_setvect(0x10,new_int10),
    _dos_setvect(0x13,new_int13),
    _dos_setvect(0x21,new_int21),
    _dos_setvect(0x25,new_int25),
    _dos_setvect(0x26,new_int26),
    _dos_setvect(0x28,new_int28),
    _dos_setvect(0x2f,new_int2f),
#define PARAGRAPHS(x)   ((FP_OFF(x) + 15) >> 4)

    /* release unused heap to MS-DOS */
    /* ALL  MALLOCS for TSR section must be done in  TSR_INIT() */
    /* calculate top of memory, shrink block, and go TSR */
    segread(&sregs),
    memtop = sregs.ds + PARAGRAPHS(ptr) - _psp,

    _dos_setblock(memtop,  psp, &dummy),
    _dos_keep(0, memtop),
}
```

When compiling the MULTI TSR example under Microsoft C 6.0 we ran across a code optimization "gotcha." Notice that the new int28 function simply sets up the task counting variables so that the swapping will become active. The code then sets the int 28 active semaphore and waits for it to be cleared.

```
int_28_active = 1,
while (int_28_active)
    ;
```

The idea is that this code is to wait until a task swap occurs. During the task swap int 28 active is set to zero.

But when compiling with full optimization the compiler sees that int 28 active is initialized to 1 is not altered in the while loop. Therefore it figures this is an infinite loop and generates a JMP \$

What it does not know is that the timer interrupt routine will clear this flag. To avoid this problem but still allow optimization, declare the int_28_active variable with a "volatile" attribute:

```
volatile int int_28_active;
```

This ANSI C keyword tells the compiler that the variable may change from an external source.

This multitasking TSR is a simple example to which a few enhancements could be added. Memory could be swapped to disk or EMS as needed. The TSR could provide a pop-up service where background operations can be controlled dynamically. If keyboard and CRT I/O is required by the background task, you must be careful to save and restore the appropriate settings. You also must not switch tasks while in the middle of a BIOS video service. For a true multitasking system, MS-DOS alone is probably not the way to go. Commercial multitaskers such as Windows or DesqView give you much more functionality. But such systems use many of the same principles outlined here.

CHAPTER 10

Command Interpreters

by Jim Kyle

Every operating system that permits more than a single program to run requires some sort of command interpreter. In the earliest days of computing, the human operator interpreted command words by picking out the correct program card deck and setting the system in action. Now a program often called the shell because it surrounds the system kernel but more commonly a command interpreter does the job. The command interpreter prompts the user for input and then reacts to that input.

For most users, a command interpreter is the closest contact they ever have with an operating system. The familiar C> prompt from COMMAND.COM, the character-based command line shell that comes with MS-DOS, is almost universally called the DOS prompt, although the interpreter is not in fact part of MS-DOS itself. Alternate interpreters such as 4DOS.COM and the MKS Korn Shell are also available.

This chapter examines first the basic service requirements that must be met by any command interpreter. It then studies COMMAND.COM, the DOS 6 program, specific examples of these requirements. While examining best techniques such as how a program expresses service and how it invokes services that DOS provides to complete the task of executing another command interpreter. The first section concludes with a small program that can substitute COMMAND.COM. This program serves to illustrate exactly what the requirements are for executing a command interpreter.

With the basic requirements established, the chapter discusses COMMAND.COM's search for the three types of files. It opens a section on information about the environment, how it works and how to locate COMMAND.COM itself. Finally, it covers DOS services and a number of other routines for locating and dealing with environment variables. Since the environment strings contain essential information such as the command interpreter's name and the path to the interpreter itself.

Next, we examine some alternative command interpreters that are now available, together with some shells that are actually shell extensions to COMMAND.COM.

The chapter concludes with a sample program that combines the use of the interpreter and undocumented features to permit resetting of either the master environment or the currently active copy. It also suggests how TSRs can work with a command interpreter that supports the undocumented DOS stack. INT 21h services the command interpreter need not provide for support so long as it provides an adequate interrupt handler for the service.

Several appendixes cover important aspects of the DOS programmer's interface not covered in this chapter. Appendix B looks at the command interpreter INT 21h services, DOS's interrupt routines. Appendix C discusses how to install and remove TSR programs. Appendix D, "The Extended Control-Break Function," is also discussed in detail.

Inside COMMAND.COM

The basic requirements for any command interpreter are as follows:

- To provide a means of obtaining commands from the human operator
- To act on them by dispatching appropriate processes

An additional requirement is that these actions be enclosed in a loop so that more commands may be issued after the current command has been processed.

Before we look at the details of these requirements, let's see just what happens inside COMMAND.COM itself. To interpret these details in perspective, the summary that follows resulted from an NTRSPY session using DOS 5.0. The script reported all calls to INT 21h and INT 2Fh. I then edited the NTRSPY report to include only one cycle around COMMAND.COM's inner loop and to remove excessive detail not directly related to the nature of the actions. I have added comments to the report to help explain what COMMAND.COM is doing at each point.

The first sequence is the return to COMMAND.COM's loop following execution of the previous command:

```
   ret from child process
I21 at FFFF:0535, AX=4D00  Get exit code  Exit Code 00h, Exit Type 00
I21 at FFFF:B4D3, AX=4800  ALLOC FFFFh paras FAIL (0008), only 89E0h available
I21 at FFFF:B4EC, AX=48AD  ALLOC 89E0h paras returned seg 161Fh
I21 at FFFF:B723, AX=2522: Set INT22 ==> 0B40:0577
I21 at FFFF:B72A, AX=2523: Set INT23  ==> 0B40:014B
I21 at FFFF:B731, AX=2524: Set INT24 ==> 0B40:0156
I21 at FFFF:B60A, AX=3F24  Close 0005 through 0013
```

COMMAND.COM first retrieves the exit code returned by the previous process and stores it in an internal variable. COMMAND.COM then releases back all available RAM that the previous process (or any of its own overlays) may have used. This is apparently done so that COMMAND.COM will not run out of memory in the event that it needs to reload that part of itself. Next, the three interrupt vectors saved in the PSP are restored to point to routines within COMMAND.COM itself, and all open handles above the standard ones are closed.

Note that after the preceding calls to INT 21 were issued from the HMA, this could indicate that they were processed by DOS-HIGH. However, a similar trace (not shown) run from DOS=LOW instead of COMMAND.COM reported a different sequence of calls to do the same things. So this sequence is not part of DOS itself. As you shall see later, COMMAND.COM internally puts these calls to the HMA if you run DOS=HIGH, and that's where these calls originate.

With cleanup from the previous process nearly done, COMMAND.COM next resets its internal critical-error handler to its own routine via INT 2Fh AX=122Eh. This is followed by calls that apparently ignore any error conditions encountered (perhaps drive not ready) and make the output of a CR LF pair to the redirected STDOUT handle. The second block of this part of the trace identifies the line generated at 0AE5:0C3E by the interrupt 2Eh instruction executed at 0AE5:0C3C:

```
INT 2F << 9672:5119, AX=122E  DOS HOOK  GET/SET ERROR TABLE
=== 2F >> AX=122E, BX=0014, CX=0000, DX=5E00
INT 2F << 9672:5128, AX=122E  DOS HOOK  GET/SET ERROR TABLE
=== 2F >> AX=122E, BX=0014, CX=0000, DX=5E02
INT 2F << 9672:5137, AX=122E  DOS HOOK  GET/SET ERROR TABLE
=== 2F >> AX=122E, BX=0014, CX=0000, DX=5E04
INT 2F << 9672:5146, AX=122E  DOS HOOK  GET/SET ERROR TABLE
=== 2F >> AX=122E, BX=0014, CX=0000, DX=5E06
INT 2F << 9672:5173, AX=122E  DOS HOOK  GET/SET ERROR TABLE
=== 2F >> AX=122E, BX=0014, CX=007B, DX=5E08
```

```
I21 at 9672:51B3, AX=6300  Get Lead Byte Table: 9672.5E08
I21 at 9672:0199, AX 3800  Get/Set Country Code: 9672 985A

I21 at 9672 5418, AX=4000  Write to 0001  00h 0Ah
```

The execution is now complete, so COMMAND.COM generates a prompt for display, building it from the current drive code and current working directory to satisfy my "pg" PROMPT specification. It is written to STDOUT (handle 1, COMMAND.COM thereby has a character, see Chapter 8) using a slow-method function INT 21h AX=4008h and 4009h just in case a redirected printer needs to be flushed and restarted. I removed extraneous lines from the following excerpt:

```
I21 at 9672 01EE, AX=1900  Current drive is: 03
I21 at 9672 1ED3, AX=475C  Get CWD for 00 returned UDOS2\ISPY
I21 at 9672 5418, AX=4000  Write to 0001  D:\UDOS2\ISPY
I21 at 9672:1EA8, AX=023E: Display Char '>'

I21 at 9672 02A8, AX 5D09  Flush redir printer output
INT 2F << FDC8 A50C, AX=1125  REDIRECTOR  Get/Set stream state

I21 at 9672 02B2, AX=5D08  Set redir printer: 01
INT 2F << FDC8 A50C, Ax=1125  REDIRECTOR  Get/Set stream state
```

With the prompt displayed, COMMAND.COM then calls DOSKEY using INT 2Fh to find the keyboard buffer. If DOSKEY is active, since DOSKEY is not active, this call has no effect and the next call to 21/0A is necessary to get the typed input. With DOSKEY active, the call to 21/0A would be skipped over. COMMAND.COM spends most of its execution time inside either DOSKEY or 21/0A, waiting for keystrokes:

```
INT 2F << 9672 02BC, AX=4810  DOSKEY  Get input
==  2F >> AX 4810, BX 858C, CX 00F9, DX=8859

I21 at 9672 02C4, AX=0A0D: Buffered Input to 9672 8859
```

When I press ENTER to end the input, control returns to COMMAND.COM. The program echoes a CR LF pair to acknowledge input, then parses the command line to determine what it should do next:

```
I21 at 9672.5418, AX=4000: Write to 0001. 00h 0Ah

I21 at 9672 0313, AX=2901  Parse FCB  mode 01) from 9672 8BDE to 9672 8E05
I21 at 9672 0394, AX=2901  Parse FCB (mode 01) from 9672 0081 to 9672 005C
I21 at 9672 03B1, AX=2901  Parse FCB (mode 01) from 9672 0081 to 9672 006C
```

The first parse looks for a term such as DIDIT. The string DIDIT is, in this example, representing the name of a simple program or a user-installed command (see the discussion later in this chapter). COMMAND.COM makes two calls to 21/AE00 just for this test, but other command interpreters use only a single call:

```
INT 2F << 9672 2BEC, AX=AE00  INST CMD  Check of DIDIT
                        CH=FF
=== 2F >> AX AE00, BX 8B0C, CX FF00, DX=FFFF, returns 00
INT 2F << 9672 2BEC, AX=AE00  INST CMD  Check of DIDIT
                        CH=00
=== 2F >> AX AE00, BX 8B0C, CX 0000, DX FFFF, returns 00
```

The return values of 00 from both these calls tells the command interpreter that DIDIT is not an installable command. COMMAND.COM then examines its list of internal commands and does not find DIDIT, so it errors. The next step is to try to locate a file of that name in the current working directory. The confusing calls seen to the Redirector routines is built into the DOS calls to detect if a file appears to be a case-reference to a remote drive happens to be made:

```
I21 at 9672 32ED, AX 1A00  Set DTA to 9672 96D5
I21 at 9672 34E9, AX=4700  Get CWD for 00 returned  UDOS2\ISPY
I21 at 9672:34F4, AX=4E00  FindFirst:  didit.???
```

```
INT 2F << FDC8 ABA5, AX 1123  REDIRECTOR  Qualify name:  d:dir ???
  name not resolved returned 0000
```

[illegible] the return value 0000 indicates that such a file exists. Were the return value non-zero, COMMAND.COM would repeat the previous step for each directory named by the PATH environment variable. Because in this case DIDIT.COM exists in the current working directory (CWD), COMMAND.COM starts to load DIDIT.COM, DIDIT.EXE, or DIDIT.BAT. Comparison of the file type returned in the DTA to the Find First call indicates that the file found is DIDIT.COM, so no additional searches are needed. COMMAND.COM releases the memory it grabbed earlier then calls INT 21 function 4B00 to load and start DIDIT.COM as a child process. Again an embedded call to the redirector appears:

```
121 at 9672:3362, AX 4700  Get CWD for 04 returned  UDOS2\ISPY

121 at 9672:29FF, AX=4908  FREE seg 161FA

121 at 0B4D:01DC, AX 4B00  Loading  D:\UDOS2\ISPY\DIDIT.COM
INT 2F << FDC8 ABA5, AX=1123  REDIRECTOR  Qualify name  D:\UDOS2\ISPY\DIDIT.COM
  name not resolved
```

DIDIT.COM starts by outputting the string "Loaded and run", then it terminates via INT 21 function 4C00, the normal DOS termination function. Since our script does not contain any commands to terminate or remove files from the virtual drive, the redirector has no reason to clean up and issue a "remote close." Then the program returns from the INT 21 4B00 call, beeping once to signal the end of the batch loop and ending our example:

```
121 at 1628:0007, AX 0900  Print String   Loaded and run

INT 2F << FDC8 95E2, AX 1122  REDIRECTOR  Cleanup at termination
INT 2F << FDC8 6DC3, AX 111D  REDIRECTOR  Close all remote files

   ret from child process
```

At this point the redirector returns to the shell where we started. The shell retrieves the exit code, grabs the errors or extended errors if any were recorded, and restores the interrupt vectors. Although the DIDIT.COM program made no changes to the COMMAND.COM as well as did other command interpreters, it is good practice to restore the vectors even if we believe the subprograms did them in the first place.

Don't let the redirector's complexity scare you. These calls involve networking capabilities (see Chapter 8 and server-based redirection (as in Novell and others). Later in this chapter we look at command line redirection.

To summarize, the command interpreter shows a prompt, gets operator input, determines how to respond to that input, and does so by either executing an installed command, running an internal command, [illegible] or loading and executing an external program. When one of those three actions completes, control returns to the loop: the interpreter retrieves the exit code for an external program, [illegible] operations, and does it all over again. The key MS-DOS functions are those that get keyboard input and display output and execute processes.

Requirements of a Command Interpreter

Obtaining Operator Input

The most essential requirement for any command interpreter is that it obtain commands to be interpreted. Without that nothing else has a reason to exist.

You've seen that operator input usually comes from keystrokes entered directly by the user in response to a prompt from the command interpreter. There are, however, several alternate methods, all of them frequently used.

The DOS Prompt The command interpreter usually signals the user that it is waiting for input by issuing a prompt message (usually known as simply as "the prompt"). Some interactive shell programs turn on the cursor or the mouse pointer to indicate that input is needed but more often these programs display their normal screen when seeking input so that the text present on the screen serves as the prompt.

In most modern multitasking environments such as Windows, the prompt is always present because input can be accepted even when other programs are running. In this case the mouse pointer often changes to an hourglass shape when input cannot be accepted due to the temporary existence of a system modal condition.

In the more conventional command line operation the prompt consists of relatively short sequence of characters. The default prompt message of COMMAND.COM is simply C:\> where C: indicates the drive letter of the current disk and \ is simply a visual delimiter. Virtually all command interpreters though give the user the means to modify the prompt into whatever form one might be desired.

Although a dedicated PROMPT command is used to define custom prompt messages the actual message is stored as a string in DOS's environment space and can be changed in the same manner as any other environment string. Many hard disk users use PROMPT pg (where the default C:\> prompt is the equivalent to PROMPT ng). For example COMMAND.COM logs showed how this prompt is produced. In addition ANSI.SYS can be used to put the current logical location at the top left corner of the screen for example where the usual prompt appears in its normal place.

Keystrokes The normal source of input to the command interpreter is the system keyboard but it is activated only as a last resort. If the interpreter is unable to get input from any of the alternates.

Unix experiences backward approach to many has every logical basis. Users can start applications using the alternate input sources to the keyboard to have the job. This method can however be frightening to the inexperienced user. Let's defer examination of the possible confusion until you see what alternatives to the keyboard exist.

When the keyboard is the source input most command interpreters use the standard DOS buffered keyboard input function (int 21h function 0Ah). This function (0Ah) is known that input is function provides through several of the Ctrl keys that offer limited editing capability which we explore in more detail later in this chapter. Note that the editing capabilities such as these are a feature of the input function not of COMMAND.COM itself.

Command line editing systems (Unix shells such as CED) work INT 21h and supply their own Read String function. Even these can use the editing keys programmed into COMMAND.COM that are invoked via DOS. These programs include DESQview, SYMDEB, DOSKEY (the command line editing supplied with DOS 5.0 does not hook INT 21h instead it provides separate interface INT 2Fh AX=4810h) which a program such as COMMAND.COM must explicitly call as shown in our earlier example.

Unlike other operating systems keyboard input to the command interpreter in DOS is not forced. The processor passes to the interpreter exactly as you type it except for characters erased with the backspace keys.

All command interpreters software with MS-DOS that I have examined have a size limit of 127 characters for their keyboard input. This limit is imposed as you'll find out in the PSP (Chapter 7) which allows only 128 bytes for the command tail. Of these 128 bytes one is used by the character count and one by the CR character that terminates the input string.

Although it would be possible to extend this limit by a few bytes because the command line is never copied into the PSP no external interpreter does so. Few simplistic must provide a maximum 128 byte input buffer although at least one 4DOS allows you to configure it for larger buffer sizes.

Batch Files Almost every application requires a relatively complex series of commands in order to get the desired action started. Batch files provide the most generally used method for supplying these

...ers. To keep the commands into the stuffed buffer at once, and then the entire sequence is pumped ... command interpreter when you invoke the batch file. Command interpreters treat a batch file ... special type of command. Although different interpreters process these files in different ... the general scheme is that the interpreter reads the file one line at a time, then executes the com... in the line. Then the interpreter goes back to read the next.

... COMMAND.COM closes the batch file each time a line is read and reopens it to read ... next line. This makes it possible to use batch files with a single drive system by having a copy of ... disk in the drive. Even if several copies are named the same and have the same content, the com... interpreter is smart enough to realize that the disks were swapped between lines. This action does, ... also make batch file operation quite slow.

Batch Enhancers and Compilers Batch files are so widely used that several firms offer batch language enhancement programs such as BE Batch Enhancer in the Norton Utilities, EBL ... the Essential Batch Language, and several PC Magazine utilities such as Mentor Method's BATCH MAN. Recently, batch compilers have become popular as well. In addition to Wenham Software's BAT-COM, ... Developer's Toolkit for *PC Magazine* (August 1990) has published a batch file compiler. Dave Pearson's BAVET. These compilers turn BAT files into executable COM or EXE files.

... is a big step forward. As is well known, the SET statement in a BAT file alters the master ... (as explained earlier in the section "How COMMAND.COM Uses the Environment"), but a ... program that attempts to change the environment by a COM or EXE program results only in ... changes to the program's local copy of the environment, which then gets thrown away when the program exits.

... however, the proper semantics of the SET statement be preserved when a BAT file is com... to a COM file. Simple. The compiled SET statement uses undocumented DOS 3+ after the ... master environment. Then except ... create a BAT file where a SET statement is compiled with ... COM file, code makes undocumented INT 21h function 52h.

... to point to the DOS List of Lists, which contains at offset -2 the segment of the first MCB in user memory. To search the MCB chain, the program can find the master ... (which is ... data later on in this section "Other Ways of Locating the Environment"). In any case, the popularity of batch file compilers will, for better or worse, ... more programs that rely on undocumented DOS functions and data structures.

"Losing" Stuffed Commands

Only the command interpreter can obtain input directly from the batch file, it's not possible to provide direct input to your programs by lines typed into any batch file. However, it's possible to use special utilities to stuff input into the keyboard buffer, where your programs can find it, and these utilities can be called from the batch file. This is useful with programs that do not take command-line arguments.

One such keyboard stuffer is Charles Petzold's KEY FAKE.COM, available in the book *PC Magazine DOS Power Tools*. KEY FAKE is used here to illustrate a feature of batch files that, although seemingly obvious, appears to cause a lot of confusion. Any other keyboard stuffer serves equally well.

The following batch file creates a file called FOO.BAR, containing the single line "hello" (the 13 26 13 emits a newline, ^Z, newline sequence):

```
echo off
key fake "hello" 13 26 13
copy con foo.bar
```

Note that input is stuffed into the keyboard buffer before the COPY CON command is invoked. If you want to stuff both the input and the command into the keyboard, however, the command must go first.

```
echo off
key-fake "copy con foo.bar" 13 "hello" 13 26 13
```

So far so good. Now let's add a line to the end of the batch file:

```
echo off
key-fake "copy con foo.bar" 13 "hello" 13 26 13
echo Done creating FOO.BAR
```

What happens when you run this? The second command happens before the first command:

```
C:\UNDOC\KYLE>tmp
Done creating FOO.BAR
C:\UNDOC\KYLE>copy con foo.bar
hello
^Z
    1 File(s) copied
```

The message that signals that the operation is complete is displayed before the operation begins! Just adding a line to the end of the batch file somehow caused the COPY CON command to be deferred.

It gets worse. Do the keyboard stuffing inside a loop, and the COPY CON command never gets executed, resulting in an infinite loop:

```
echo off
del foo.bar
:loop
key-fake "copy con foo.bar" 13 "hello" 13 26 13
if not exist foo.bar goto loop
```

Simply putting a command inside a loop causes the batch file to stop working! What is going on here?

If as a final experiment, you return to the original idea of putting the COPY CON command itself in the batch file and stuffing only its input into the keyboard buffer, everything starts working properly again.

```
echo off
del foo.bar
:loop
key-fake "hello" 13 26 13
copy con foo.bar
echo Done creating FOO.BAR
if not exist foo.bar goto loop
```

What you have just seen merely illustrates that the command interpreter exhausts all batch file activities before looking in the buffer for keyboard input. Therefore, unless the keyboard stuffer happens to execute as the last command in the batch file, the stuffed command isn't executed at the correct time.

This detail of command interpreter operation seems rather obvious, yet I spawns at least one question per week on the major network forums that deal with hardware and software problems. The rule to follow in order to avoid the problem is simple: Invoke commands directly from the batch file, not by stuffing the keyboard buffer; provide only program input through the buffer.

Interpreting Operator Requests

Once the operator's input has been obtained, it must be put into a form acceptable to MS DOS that is, it must be parsed for the parameters as set forth, interpreted, and acted on. This section first describes the various methods of parsing the input, then discusses how the input is interpreted, and finally deals with the execution of internal commands. Any input not recognized as an installed or internal command passes to the dispatching procedure as a possible external command that it must load from a file.

Parsing for Inclusion in the PSP The standardized parsing done by DOS command interpreters takes three forms: stock, CP/M, the major difference is that MS DOS includes INT 21h Function 29h, fully documented, to perform the parse for you.

In this standardized parse, certain characters are treated as separators and only a few of these are white space. These include the stock spaces, the tab character, the switch character (normally a forward slash, although some versions of DOS have it changed to a hyphen), see below, the comma, the equal sign, the semicolon, and the quote. Several of these have additional syntactic significance, but all are recognized as terminating the end of the possible command name.

The parse begins with the removal of leading separator characters at the front of the input line. When a nonseparator character is found, the parse routine converts it to uppercase if it is alphabetic and moves it to a parse buffer. From that point onward, the separator characters are encountered, all characters encountered in the parse buffer are converted to uppercase if necessary. When the terminating separator is found, the parse pointer is left pointing to it.

If the command in the parse buffer is found to be one of the installed commands or an external program, the command processor will execute it. If it is an internal command, the command interpreter usually performs the next step. In other words, a PSP is available for the rest of the parsing procedure.

All the input characters from the input buffer are moved to the command tail area of the PSP, starting with the command's execution starting point at offset 81h, and the count of those characters is stored at offset 80h. None of these characters is case converted during the move.

Next, the first complete word of any on the command tail is examined to determine if it could be a filename. (A filename must contain no characters that would not be valid in a filename, as second extension fields are allowed and a separator character preceding it can be a period.) This permits the CP/M and DOS 1.x method of specification, such as A:FILENAME.EXT, to be accepted.

If the word passes these tests, it is converted to FCB format, which includes case conversion, and copied into the FCB area of the PSP at offset 5Ch (see Chapter 7). The drive code corresponds to the FCB byte, followed by the filename portion padded with blanks, and the extension. The period after the name is omitted and the extension goes into the next seven bytes of the default FCB area. The process is repeated for the second complete word of the command tail to fill in the FCB2 area of the PSP at offset 6Ch.

The parsing of the command line is carried out by CP/M programs and the syntax of many of the DOS commands is dictated by these early times. In DOS 1.x many programs took advantage of the parsing and the fact that the first two command line arguments from the filename fields of FCB1 and FCB2. Some programs still do this. Rather than have to form their own parsing routines, the command processor and command line were made available. However, these routines are not capable of handling switch characters, redirection, and pipes. Since DOS 2.x their usefulness began to fade and today they are rarely used. Unfortunately, some programs still depend on them, showing the persistence of CP/M vestiges.

Unlike the standard parse, where the command interpreter has to an internal parsing buffer, the first word of input converted to uppercase and it has in the new current PSP the two FCB areas and the command tail data. The next step is to determine whether the input was actually a valid command. But first a little more on the subject of [illegible].

SWITCHAR If you've ever needed to switch between DOS and UNIX machines, you're aware that whereas UNIX uses the forward slash (/) for paths and hyphens (-) for command line options, MS-DOS uses the backslash (\) for paths and the forward slash (/) for command line options. Prior to DOS 5.0, the convention applied to COMMAND.COM more than to DOS itself, since DOS 5.0, though, it's built into DOS and cannot be modified.

What a mess. An undocumented DOS function (INT 21h, function 3701h) can help clean up this situation, if you use a version prior to DOS 5.0. This function, described in the Appendix, changes the switch character. This facility was documented for a brief time in the DOS user interface (the SWITCHAR option in the DOS 3.0 CONFIG.SYS), but then it was made undocumented.

This function can be incorporated into a tiny utility (see, e.g., SWITCH.EXE) that sets the DOS SWITCHAR. Packages of UNIX utilities for DOS, such as the MKS Toolkit, include a similar utility.

Figure 10-1. SWITCHAR.C

```
/*
SWITCHAR.C -- uses undocumented DOS function 3701h
switchar -   changes DOS switch char to - and path char to /
switchar \   restores DOS switch char to / and path char to \
*/

#include <stdlib.h>
#include <stdio.h>
#include <dos.h>

main(int argc, char *argv[])
{ int c = (argc > 1) ? argv[1][0] : '-';
#ifdef __TURBOC__
  _DL = c;
  _AX = 0x3701;
  geninterrupt(0x21);
  _AH = 0;   /* value returned in AX */
#else
  _asm {
    mov dl, c
    mov ax, 3701h
    int 21h
    xor ah, ah   ; value returned in AX
    }
#endif
}
```

Almost all COMMAND.COM since DOS 4.0—including the DIR command—supports the SWITCHAR setting. SWITCHAR with function 3701h is useful only when other programs, in particular COMMAND.COM, support it. Function 3700h (get SWITCHAR) is not DOS 5.0 if this SWITCHAR program won't even work, but it exists in DOS still works. Function 3701h (set) was recollected at all, making the program useless in DOS 5.0 and above.

Command Line Redirection and Pipes One feature that has existed in COMMAND.COM since DOS 2.0, and which consequently is also in all the popular alternate command interpreters, is the ability to redirect input and output. This means that the command interpreter can "throw a switch" so that input for a process comes from a file rather than from the keyboard and so that dependent output from a process goes to a file rather than to the CRT.

Together with this feature, which came from UNIX, "pipes" can be created to hook two processes together—that the output of the first becomes the input to the second.

The capabilities, the first versions of DOS documented the method by which they are activated, so let's look first at how COMMAND.COM performs this magic in DOS 5.0. We'll create a simple C program that performs its own redirection, using command line arguments to specify the input and output names.

Here's how command line redirection works when COMMAND.COM processes this line

```
D:\UDOS2\1SPY> DEV >xyz
```

The redirection symbol (>) specifies that output is to go onto the file XYZ rather than to the screen. DEV is the device driver tracing program from Chapter 7, but any program could have been used. And though this example deals only with redirection of output, input redirection is done in exactly the same way.

COMMAND.COM processes "DEV >XYZ" in almost the same way that it processes a plain "DEV" command. Only after DEV has been determined to be an external command, the file located, and the current working directory's name retrieved, does the command line redirection cause a change in how COMMAND.COM processes DEV. COMMAND.COM creates a file named XYZ in the current working directory.

The System File Table has an entry for the handle returned by the Create File call (INT 21h AX=3C00h) for this file. It proceeds to XENIX 3 handle 1. All output sent to STDOUT from this point on goes into the XYZ file rather than to the CRT. COMMAND.COM then continues just as in the earlier example to load and run the program DEV.

After DEV has finished, COMMAND.COM detects that STDOUT handle 1 points to a different System File Table entry from STDERR handle 2. This indicates that STDOUT has been redirected. It closes the COMMAND.COM copy of STDOUT and restores it to the same SFT entry as handle 2 before dropping into the loop that closes the 15 user-controlled handles. (Hmm, what good program do you know how to redirect STDERR?)

Because of the device independence achieved by the use of file handles and device drivers (discussed in Chapter 7), only these two additions to the normal inner loop of COMMAND.COM were required to redirect the output from DEV into the file XYZ rather than onto the screen.

The only difference between this redirection as described here and pipes that connect processes is that the command processor interpreter actually creates a temporary file to serve as a pipe and redirects output from the first process into that file. The interpreter then directs the file to the second process as its input. Then, after the second command interpreter loop that generates the prompt and waits for keyboard input is stopped for the second process, so that the single piped command actually does the same thing as two separate commands with a common redirection file connecting them. Finally, the command interpreter deletes the temporary file when it's no longer needed.

You've seen how COMMAND.COM deals with command line redirection. Now let's see how to build a redirection program (Figure 10-2). The key is the dup2 function.

Figure 10-2. REDIR.C

```
/*
 *  REDIR.C - August 1992 - Jim Kyle
 *      Shows how to redirect STDIN and STDOUT
 *      Tested only with BCC++ in ANSI C mode:
 *              bcc redir.c
 */
#include <stdio.h>
#include <string.h>
#include <io.h>
#include <process.h>

int main( int argc, char **argv )
{ char cmdbfr[126] = "";
  FILE *NewIn = NULL, *NewOut = NULL,
  int oldin, oldout;
  int retval = 255, i;

  if( argc < 4 )
    { puts( " Usage. REDIR In Out Command ... " );
```

```
    puts(     where In = $TDIN or name of input file" ),
    puts( "         Out = STDOUT or name of output file" );
    puts(     and Command = normal command line to be run " ),
  }
else
  { if( stricmp( argv[1], "STDIN" ) != 0 )    /* if file named    */
    { NewIn = fopen( argv[1], "r" );   /* open the file to read */
      if( !NewIn )                          /* quit if any error */
        { perror( argv[1] );
          return retval;
        }
      oldin = fileno( stdin );             /* save for restoring */
      dup2( fileno( NewIn ), fileno( stdin )),/* force to stdin */
    }

    if( stricmp( argv[2],  STDOUT  ) != 0 )  /* if file named     */
      { NewOut = fopen( argv[2], "w" )   /* open the file, output */
        if( !NewOut )                       /* quit if any error */
          { perror( argv[2] );
            return retval;
          }
        oldout = fileno( stdout ),          /* save for restoring */
        dup2( fileno( NewOut ), fileno( stdout )),/* force stdout */
      }

    for  i=3, i<argc, i++ )           /* rebuild the command line */
      { strcat( cmdbfr, argv[i] ),
        strcat( cmdbfr,     ),
      }
    retval = system( cmdbfr ),        /* then exec, save exit code */

    if( NewIn )                         /* restore STDIN if needed */
      { fclose( NewIn ),
        dup2( oldin, fileno( stdin )),      /* use original value */
      }
    if( NewOut )                              /* and also STDOUT */
      { fclose( NewOut );              /* close to update directory */
        dup2( oldout, fileno( stdout )),    /* use original value */
      }
  }
 return retval;                               /* return exit code */
}
```

Rather than create such an issue by attempting to parse an input command line to detect a redirection request, REDIR.C just requires that you specify both input and output paths as the first two command-line arguments. If the first argument is "STDIN", no input redirection is performed. If it is anything else, that argument is passed as a file or device name to the fopen() function to be opened for reading.

Similarly, the second argument is compared to "STDOUT" to detect a request for output redirection.

After these two arguments are processed, the rest of the input command line is reassembled into a new command line and passed on to the normal command interpreter through the system() function. Any value returned by system() is saved in the local variable retval to be passed back as REDIR's own exit code. We look at this exit code business a little later.

Before returning to DOS, REDIR closes any redirection files or devices that have been opened and attempts to restore the corresponding streams to their original devices. With these tasks taken care of, REDIR then returns the saved exit code as its own and goes back to DOS.

The dup2() function is a standard C library function whose MS-DOS implementations are documented in INT 21h, AH=46h, "Force Duplicate File Handle."

Distinguishing Internal and External Commands Every command interpreter implemented for a microcomputer has included at least some internal commands; most have also provided a means of executing external commands.

What distinguishes an internal from an external command is the location of the code that executes it. All internal commands are built into the command interpreter itself; external commands reside elsewhere. In some systems, including Cromix, CP/M, TRSDOS (some microprocessors), and Honeywell's CP/M, external commands have been stored in special library files. In MS-DOS, however, they are stored as individual program files.

CP/M-80, on which the MS-DOS architecture was derived, contained only five internal commands. All other commands were external, stored as COM (for COMmand) files in a memory image format. The internal commands were DIR, REN, TYPE, ERA, and SAVE. The first four of these were functionally the same as their MS-DOS descendants. The other one provided the means for creating the necessary COM files. The second SAVE argument specified a number of 256-byte "pages" to be saved from memory. To load a memory-resident program into RAM so that SAVE could do its thing, you had to use DDT.COM, a built-in machine-language debugger.

The next version of MS-DOS added a bit more to the set of internal commands. COPY, which in CP/M had been a separate external utility called PIP (Peripheral Interchange Program), was moved into the command interpreter as an internal, and DATE, TIME, VER, and VOL were added. With each new version, additions were made to the set of internal and external commands associated with them. The use of batch files gave birth to several internal commands to help make batch files more useful.

By the time MS-DOS made it to version 3.3, the list of internal commands had grown to 36. One undocumented command was added with version 4.0; two documented commands at version 5.0, and one in version 6.0.

The undocumented TRUENAME command displays the full path name of a file given the file's name as its argument. The SUBST replacements are translated from logical back to physical form, and any expected path is made explicit. For instance, if you were to issue the command SUBST E: C:\ZAP\ZIP and make E: your current drive, the command TRUENAME I?SS4 displays the string C:\ZAP\ZIP\I?SS4. This command corresponds exactly to INT 21h Function 60h, which is explained in more detail in Chapter 5 of the DOS System Operation of the new LOADHIGH and DEVICEHIGH commands is discussed in the discussion of the HMA and UMBs.

Let's get back to how the command interpreter determines whether it is dealing with an internal command or an external one. It makes a simple search of its internal command list. If the input command matches one of the entries in that list, the internal command is executed. If not found, the interpreter treats it as a possible external command.

DOS 3.3 introduced a hook into the internal command list by way of ESRs that contained the COMMAND.COM command table. Unfortunately, this hook was not documented with the exception of APPEND. In DOS 4.x, a method was provided to create a private command table. The first place and DOSSHELL, which appeared in DOS 4.0, are two programs that exploited services provided in DOS 5.0 that original DOSSHELL was to be replaced by a totally different package under the same name created by Central Point Software (pcs.com). We provide source code for an installable command later in this chapter that hooks into the MS-DOS provides for command interpreters.

Note that before the command interpreter parsed before any attempt is made to locate the corresponding program, the command interpreter treats the percent character as having special meaning. It searches for command line arguments when found in a batch file. It also identifies environment variables. If followed by a character that is neither an argument identifier nor an environment variable, the character normally is thrown away.

rather than passed on to the command as part of the command line. This is true only when input is taken from a batch file.

Sometimes the caret character needs to be kept through. The classic case is the FOR command with its percent variable reference, as in: FOR %N IN (*.*) DO type %N. That one works perfectly from keyboard input, but if it is included in a batch file, the percent characters will be dropped and the command becomes syntactically in error. To solve this problem, whenever COMMAND.COM or its functional equivalent locates a percent character followed by another percent character, which COMMAND.COM passes on to the program. This is exactly the technique FOR %N IN (*.*) DO type %N requires. This action is analogous to the C language convention regarding \\ which is required when you use it in a string, but even when you want a single \ to appear.

Finding and Executing Internal Commands Because the internal command list, including any installed extended commands, is searched first, it is a tricky matter to copy COMMAND.COM to create a program that has the same name as one of the internal commands. That is, if you name a program file TYPE.COM and find that the external command TYPE takes its place when you try to execute it, the program is not the command interpreter, although it runs your own program perfectly when invoked from the DOS EXEC function. DEBUG.

When COMMAND.COM searches its command list for a possible internal command, it breaks off the command word at the first encountered period after the command. Thus, to continue the example of your internal TYPE.COM program, the .COM would be ignored, and the internal search would find and execute TYPE, which would then execute.

With most recent versions of DOS that permit you to specify a full path name for a command, you can solve this problem by specifying a path for TYPE.COM, such as \TYPE\TYPE.COM, if the file is in the current directory.

Various versions of the alternative command replacements attack this problem in two ways. First, they let you select a command-line switch or environment variable, or a configuration option, to control the way the search is performed. For example, you might specify that the input is truncated at a period. If you have TYPE.COM, that is what executes. Second, the search would find TYPE.COM because none of the internal commands has an embedded period.

Under an environment where programs are loaded, executed, and relocated as normally executed under DOS, the command interpreter must be the command processor of the appropriate interface environment. Otherwise, prompt code becomes incorrect. This code is contained within the interpreter itself, so the program swapping executive must load a separate copy of the command interpreter for each process spawned for the purpose of executing internal commands.

Before we leave the command COMMAND, introduced as the external command COMMAND with the /C option switch, we need to note that batch files from inside another batch file return to the original file. This feature requires about 4K additional RAM for the child copy of COMMAND.COM that is loaded. This technique can be significantly slower due to the additional disk accesses required.

Dispatching Appropriate Processes

Any name that is not an internal command or matched in the installed command list is presumed to be an external command. The command interpreter searches for a file of that name, using the PATH to determine where to search. If such a file is located, it is loaded and run. If not, the error message "Bad command or file name" tells the operator that the input was faulty. The command interpreter then returns to its top-level "get input" procedure for a fresh command to interpret.

Locating and Loading External Commands To locate and execute an external command, the command interpreter first searches the current working directory for a file having a name identical to the command word and the extension .COM. If this fails, the search is repeated using the

extension EXE. If this search fails, a third search is made with the extension BAT. Thus, if three files named DOSME.COM, DOSME.EXE, and DOSME.BAT all exist in the current directory, only the COM file will be executed as an external command.

The COM, EXE, BAT sequence is established by code in the command interpreter, not by MS-DOS itself. It can be exploited in several ways that we examine a little later, but if you want to change it, you can do so by locating in your command interpreter the nine bytes that contain the characters COM, EXE, and BAT, and changing them as you desire. This can be done on the disk copy of the interpreter or in memory using DEBUG.

If all three searches fail in the current working directory, the command interpreter looks for an environment variable named PATH. If one exists, it takes the first path listed in that string, adds a backslash character, appends the filename and extension from the command line, and repeats the three searches in the directory specified by that path. If unsuccessful, the interpreter moves on to the next path specified in the PATH variable and repeats the searches. This continues until either a file that satisfies the search is found, or the PATH variable is exhausted without finding such a file.

If no file is found, the command interpreter issues a "Bad command or filename" error message and returns the prompt. Note that this happens only after the three searches (COM, EXE, BAT) have been made in each directory specified by PATH. If you have a large number of directories in your PATH and each has a large number of files, the search may take a significant amount of time.

Dealing with BAT Files When a file is found that satisfies the search criteria, the command interpreter's next action depends on whether or not the file found was a batch file (BAT extension). If so, the command interpreter sets up a special data area in order to mark that it is processing a batch file. It must then make a note of the interpreter's status—enough data about the file to be able to find it again. The flag locations and the amount of data saved vary significantly from one version of DOS to the next.

The interpreter opens the batch file, reads its first one hundred or so bytes into the command input buffer, and replaces any redirected arguments (%1, %2, and so on) with corresponding words from the original command line. When a carriage return is encountered in the input buffer, it marks the end of the command. If any %0 arguments are found, they are replaced with the name of the batch file (without the extension). The interpreter then closes the batch file and interprets and executes the modified command. Then, instead of reading from the keyboard, ...

When a command is executed, control returns to the command interpreter. It flags to the ... that the next input is to come from the batch file. It reads the next line, usually a minimum of 32 bytes, into the ... This process continues until all lines of the batch file have been executed.

Any command can be used in the batch file, be it an internal or external command. Since DOS 3.3, ... can invoke a different batch file in subroutine fashion using the CALL ... command. Before CALL was available, it was possible to invoke a batch file that never finishes execution, ... control never gets back to the original command interpreter's keyboard input level.

Dealing with COM and EXE Files If the file found was not a batch file, the command interpreter uses the DOS EXEC function (INT 21h function 4B00h) to spawn the file's execution as a child process of the command interpreter. ... happens to the interpreter until the child process terminates.

Notice that with COMMAND.COM, it makes no difference whether a COM or EXE file was found; the distinction between the two types of executable files is made by the EXEC function based on ... the first two bytes of the file. ... EXE files have the MZ signature, and the actual file extension is ignored, except to create the file. This means that you could force a file that is really an EXE type to be found during the first search ... by giving it an extension of COM. It also means that you could take a text file, word processor document, or spreadsheet, rename it with an extension of COM or EXE, and COMMAND.COM would try to execute it as a COM file.

An alternative to changing the file's extension is to create a stub loader which is a small file of the same name except for the extension .COM. The stub loader then uses the EXEC function to spawn the original .EXE file as a child of its own. This approach makes it possible to set up all sorts of special conditions before the program file is executed, then subsequently undo them with minimal overhead.

One widespread use of this technique is in support of the third-party replacement video BIOS package UltraVision+ from Personics. UltraVision permits its users to set up a wide variety of screen options, ranging up to 132x60. These formats are compatible with any other program that is well behaved in the sense that it looks in the BIOS work area to determine what number of columns and rows are currently set. Unfortunately, many popular programs don't bother to do so because the ability to set non-standard formats is relatively recent.

To run programs that do not check the current number of columns and rows, it is necessary to set the screen format to the standard 80x25. Unfortunately, Personics UltraVision includes a utility which generates a stub loader for any desired EXE format program file. The loader first notes all pertinent information from the BIOS area and then resets to the 80x25 format. Next, EXEC is the specified program file, using its full name, including the EXE extension, and passes to it all the command-line arguments that the loader itself received. Upon return, the loader temporarily saves the exit code from the real program, restores the video to the original conditions the loader found at entry, and returns its child's exit code to DOS as the exit code it was given. The command interpreter always finds the loader with the .COM extension first, so as to start execution of the stub loader.

As a result, by using the UltraVision+ support utility, UltraVision+ is able to create a loader so we can make any program well behaved in the sense that the cost of this is a thousand bytes of overhead in code.

Another use of the stub loader idea is built into Microsoft's new support for protected-mode executables which are used in Windows/386 2.x and the now-obsolete European OEM multitasking DOS 4. These new EXE files have a normal old-style EXE header that points to a new-style NE header with the NE signature. The old-style EXE can be used to print a message such as "This program requires Microsoft Windows" or it can be used as a loader that, for example, runs Windows.

The Exitcode Idea When I said that the UltraVision loader saved the real program's exit code, you may have wondered why a loader should preserve the exit code of a special process or pass it on, when exit code is all about. As we've documented, at least as regards the method of writing a program, a program's exit code is the property of that program's creator, not of the operating system.

In order that a process should return a result code to its parent, DOS must provide a mechanism that exists specifically to transfer control from a child process back to the parent (or to the system bootstrap loader, if the appropriate program was launched at about the same time as the user's computer was switched on). In other words, a microcomputer operating system, upon the user's

An DOS process returns its exit code to its parent by the use of one of three methods. The program or the process terminates using INT 21h, Function 4Ch, Terminate with Exit Code, or 31h, Terminate But Stay Resident. It can use other methods usual to return to DOS, such as INT 20h or INT 21h Function 0, which are considered a subset of the preferred method. DOS itself

The exit code is retrieved once, and only once, after the spawned process returns to the parent and before any subsequent process is spawned. The reason for this restriction is that DOS does not provide storage for more than one exit code, so that every process overwrites the code left there by its predecessor. The child's exit code is retrieved by the DOS function that retrieves the code, INT 21h, Function 4Dh, Get Exit Code. A DOS program zeroes out that storage location in the process of retrieving the code.

COMMAND.COM provides the internal command ERRORLEVEL, which is a batch file conditional function that can be characterized as an internal IF command. ERRORLEVEL retrieves the exit code of the most recent command and compares it to a specified value. All compatible command interpreters provide this command, which can be implemented in a functionally identical manner.

If you'll recall from the discussion of COMMAND.COM's processing loop that began this chapter, you saw that the first thing COMMAND.COM does upon return from a child process is to retrieve the exit code and save it in COMMAND.COM's own data area for possible use by ERROR LEVEL later. When ERROR LEVEL is called, it uses that saved value rather than attempt to retrieve the exit code from DOS again.

Despite the exit code and ERROR LEVEL applies only to external commands, most internal commands are coded to set the ERROR LEVEL value. Because these commands do not spawn child processes, such commands do not affect the DOS exit code value. Some third-party command interpreters do extend the ERROR LEVEL idea to at least some internal commands, extending it to all commands including DIR. Note that last it would negate the whole idea because it would make multiple way decisions impossible.

Installable Commands

Function AL = install check Command of INT 2Fh available since DOS 3.3 connects what would otherwise be an external command into the internal command list of COMMAND.COM. Both the command processor and the handler for this function must be installed as a single, non-pop-up TSR. The two most common examples of such are APPEND in DOS 3.3 and higher and in the DOS 4.0 DOSSHELL facility, which is now of only historical interest since the DOS 5.0 version of DOSSHELL is totally different.

As you can see, this undocumented interrupt to install your own commands with DOS 3.3 and later is a two-piece proposition. Don't call us, we'll call you." COMMAND.COM issues calls to this interrupt at two places while parsing the input line. To use this function, you provide your own interrupt handler hooking INT 2Fh, AH=AFh.

Two calls by COMMAND.COM to Subfunction AE00h are to determine if the command is one of the resident internal commands. The other two are called only if the first call returns FFh in the AL register, indicating that the command is indeed valid. The second calls are both to Subfunction AE01h, which is expected to execute the command.

When Subfunction AE00h is called the first time, both the DS and ES registers point to COMMAND.COM's resident code. The DX register is set to 0FFFFh for unknown reasons; the BX register points to a buffer that contains a word count byte followed by an exact copy of the input line. CH contains FFh and the SI register points to a buffer that contains only the command word from the input line, uppercased and preceded by its character count. Your code must verify that the word in this second buffer is one of the names of your installed command. If it is not a match, you should clean the stack, preserve the registers in case some other installed command is expected, and return to the caller. If a match occurs, your routine should change the AL register to FFh and return to the caller.

The second call to Subfunction AE00h is identical to the first except that CH contains 00h when the command processor makes this call. COMMAND.COM makes both calls. The alternative would be to have DOS COM does the same job satisfactorily, but calls this subfunction only once.

A Subfunction AE00h returns 00h in AL, indicating that the command is not an installed command, no call to AE01h is made. Instead the command interpreter is expected to deal with the command itself.

If Subfunction AE00h is used to execute the command, the ES, DS, BX, DX, and SI registers contain exactly the same data as on the previous Subfunction although only DX and SI are again expressly loaded with the values sent to the caller. The BX register has been preserved through a couple of subfunction calls, but a future DOS version may not always retain the pointer to the full input line buffer.

Therefore, if your command accepts arguments on the input line, we recommend that those arguments be copied into a local buffer before the routine returns from the AE00h call. After executing the actual command within the AE01h call, your code should zero out the count byte in the command buffer at DS:SI. The zero count signals COMMAND.COM not to attempt to execute the command itself.

These calls to function AEh are made before the internal command list is checked, which means that you can install a command that has the same name as one of the internal commands, and your command will replace the original one. Because your own command can be a do-nothing, this offers an elegant way to disable the DEL and TRANS commands, as a system that can't be accessed by the general public.

This also permits you to add a modified front end to any existing command. You can provide an installed command with an identical name that does your front-end processing, then calls Int 2Eh (Subfunction AE00h) and does not zero out the command buffer, and returns zero from the AE00h call so that COMMAND.COM will process the internal command.

The C program shown in Figure 10-3, INSTCMD.C, illustrates all the points of dealing with the installable command interrupt services. Note that this program does not install as a TSR but instead operates as a wrapper (see "Application Wrappers" by Kaare *JR Tollnaes* in the July 1992 issue) to avoid problems in deinstalling the added command. Note that despite the repeated references to COMMAND.COM in the comments, this program actually works with any command interpreter that supports 2E. At times, the program uses the COMSPEC environment variable to locate the command interpreter itself.

Figure 10-3. INSTCMD.C

```
/*
INSTCMD.C

The  Installable Command  function is not called by a program that
wants to extend COMMAND.COM's repertoire.  Instead, you hook the
function and wait for COMMAND.COM to call you.  I don't call us, we'll
call you.)  Function AE00h lets you tell COMMAND.COM whether you
want to handle the command, and function AE01h is where you actually
handle it (similar to device driver division of labor between
Strategy and Interrupt).

Note that AE01h is called with only the name of the command; not with
any arguments.  Therefore, arguments must be saved away in AE00h.  Your'

Furthermore, while redirection is handled in the normal way in
AE01, in AE00 we get the entire command string, including any
redirection or piping. Therefore, these must be stripped off before
saving away the args during AE00 processing.

Problem with the following AE00 and AE01 handlers:  they should
chain to previous handler.  For example, INTRSPY program won't see
AE00 and AE01 once INSTCMD is installed.

The sample COMMAND.COM extension used here is FULLNAME, based on the
undocumented TRUENAME command in DOS 4+.  We simply run undocumented
Function 60h in order to provide FULLNAME.  Actually, not quite so
simple, since Function 60h doesn't like leading or trailing spaces.
These are handled inside function fullname().

The following INTRSPY script was helpful in debugging 2FAE.

; INSTCMD.SCR
structure cmdline fields
    max (byte)
```

```
    text (byte,string,64)

intercept 2fh
    function 0aeh
      subfunction 00h
        on_entry
          if (dx == 0FFFFh)
            output "AE00"
            output (DS BX->cmdline)
            output CH          ; CH=FF (first), 0 (second)
            output " "
      subfunction 01h
        on_entry
          if (dx == 0FFFFh)
          output "AE01"
          output (DS:SI->byte,string,64)

tested only for Microsoft C 6.0+ or above
    cl -qc instcmd.c
*/

#include <stdlib.h>
#include <stdio.h>
#include <string.h>
#include <ctype.h>
#include <conio.h>
#include <dos.h>

#pragma pack(1)

typedef struct {
    unsigned es,ds,di,si,bp,sp,bx,dx,cx,ax;
    unsigned ip,cs,flags,
    } REG_PARAMS,

typedef unsigned char BYTE;

typedef struct {
    BYTE len;
    BYTE txt[1];
    } STRING,

typedef struct {
    BYTE max,
    STRING s;
    } CMDLINE,

void interrupt far handler_2f(REG_PARAMS r),

void (interrupt far *old)();

void fail(char *s) { puts(s), exit(1); }

main(void)
{ /* hook INT 2F */
  old = _dos_getvect(0x2f),
  _dos_setvect(0x2f, handler_2f),

  puts( This demo of installable commands isn't a TSR.');
  puts( Instead, it just creates a subshell from which you can EXIT");
  puts("when done. In the subshell, one new command has been added:"),
  puts("FULLNAME [filename].");

  system (getenv( COMSPEC" ));
```

```
    /* unhook INT 2F */
    _dos_setvect(0x2f, old),
}

char far *fullname(char far *s, char far *d)
{   char far *s2;

    /* INT 21h AH=60h doesn't like leading or trailing blanks */
    while (isspace(*s))
      s++,
    s2 = s;
    while (*s2) s2++,
    s2--;
    while (isspace(*s2))
      *s2-- = 0;

    _asm {
      push di
      push si
      les di, d
      lds si, s
      mov ah, 60h
      int 21h
      pop si
      pop di
      jc error
    }

    return d;
error:
    return (char far *) 0;
}

void fputs(char far *s)
{   /* can't use stdio (e.g., putchar) inside 2FAE01 handler */
    while (*s)
      putch(*s++),
    putch(0x0d); putch(0x0a);
}

char buf[128],      /* not reentrant */
char args[128],

#define CMD_LEN     8

void interrupt far handler_2f(REG_PARAMS r)
{   if ((r.ax == 0xAE00) && (r.dx == 0xFFFF))
      {
      CMDLINE far *cmdline,
      int len;
      FP_SEG(cmdline) = r.ds,
      FP_OFF(cmdline) = r.bx,
      len = min(CMD_LEN, cmdline->s.len);
      if ((_fmemcmp(cmdline->s.txt, "fullname", len) == 0) ||
          (_fmemcmp(cmdline->s.txt, "FULLNAME", len) == 0))
        {
        char far *redir,
        int argslen = cmdline->s.len - CMD_LEN;
        _fmemcpy(args, cmdline->s.txt + CMD_LEN, argslen),
        args[argslen] = 0,
      /* yuk! we have to get rid of redirection ourselves! */
      /* it will still take effect in AE01 */
      /* the following is not really correct, but okay for now */
        if (redir = _fstrrchr(args, '>'))
          *redir = 0;
```

```
        if (redir = _fstrrchr(args, '<'))
          *redir = 0;
        if (redir = _fstrrchr(args, '|'))
          *redir = 0;
        r.ax = 0xAEFF,  /* we will handle this one*/
        }
      }
    else if ((r.ax == 0xAE01) && (r.dx == 0xFFFF))
      {
      STRING far *s;
      int len;
      FP_SEG(s) = r.ds;
      FP_OFF(s) = r.si;
      len = min(CMD_LEN, s->len);
      if ((_fmemicmp(s->txt, "fullname", len) == 0) ||
          (_fmemicmp(s->txt, "FULLNAME", len) == 0))
        {
        char far *d,
        if (*args)
          d = "syntax: fullname [filename]",
        else if ((d = fullname(args, buf)) == 0)
          d = "invalid filename",
        fputs(d),
        s->len = 0, /* we handled it, COMMAND.COM shouldn't */
        }
      }
    else
      _chain_intr(old),
}
```

If you run INSTALL.EXE, you first see the four line explanation of what the program does, followed by the banner line as the final step of your COMMAND.COM interpreter initializes itself. From that point on, you can type FULLNAME followed by the name of any file in the current process, and you have available the added command FULLNAME. Experiment a little with it. It is critical to the undocumented FULLNAME command that you load your DOS 4.0 and above code by way of an EXE file adapter.

Notice that INSTALL.EXE copies the arguments supplied on the input line into a buffer when servicing service 0xAE00 (hex) so that it is available when executing the command subsequently. Both arguments are in the function handler. 26

For another view of installable command processors, see Jeff Prosise's article, "Replacing Internal DOS Commands," *PC Magazine*, Dec. 31, 1991, and several other articles on 21 AF cited in the bibliography.

TSHELL, a Simple Command Interpreter

The basic architectural elements of interpreters are extremely simple. What makes them seem complicated is trying to handle all the bells and whistles that possibly exist in various circumstances with a minimum disruption of system operation. Small, secure, and yet specialized command interpreters can be and still function. Figure 10-4 shows a small TSHELL.C that you can install as the primary shell of your system.

Figure 10-4. TSHELL.C

```
/*************************************************************
 *  TSHELL.C - Demonstration tiny command interpreter        *
 *  Jim Kyle, July 10, 1990                                  *
 *                                                           *
 *  Intended only to show basic principles, not for use      *
 *  with DOS versions prior to 3.1 (EXEC function of such    *
 *  versions does not preserve stack registers).             *
 *                                                           *
 *  For Borland C compilers only due to pseudovariables      *
 *                                                           *
```

```
 *      tcc -mt -c tshell                                               *
 *      tlink /t /c c0t+tshell,tshell,,cs.lib                           *
 *                                                                      *
 ************************************************************/
#include <stdio.h>
#include <string.h>
#include <dos.h>
#include <dir.h>

char cmdbuf[128];
char *cmdlist[] = {"DIR","RUN"},
int i;
void do_dir( void )                     /* reports files in cur dir */
{ struct ffblk wkarea,
  int endir;

  if (strlen(cmdbuf) < 5)                   /* default to all files */
    strcpy( cmdbuf+4, "*.*" ),
  puts("\n    Files and sizes\n"),
  endir = findfirst( cmdbuf+4, &wkarea, 0 ),
  while ( !endir )
    { printf("%-13s   %8ld\n",
             wkarea.ff_name, wkarea.ff_fsize );
      endir = findnext( &wkarea );
    }
  putchar( '\n' );
}

/* CHEAT' Implemented RUN by EXECing COMMAND.COM. */
void do_run( void )                  /* caution, safe only for DOS3+ */
{ struct {
    unsigned eseg, clo, cls;
    long     fcb1, fcb2;
  } parms;

  cmdbuf[0] = strlen (cmdbuf+1),       /* was wrong in first edition */
  cmdbuf[1] = '/',
  cmdbuf[2] = 'C',
  cmdbuf[3] = ' ';
  parms.eseg = 0,
  parms.clo = (unsigned) cmdbuf,       /* was wrong in first edition */
  parms.cls = _DS,
  parms.fcb1 = parms.fcb2 = 0L,
  _ES = _SS;
  _BX = (unsigned) &parms;
  _DX = (unsigned)  "\\COMMAND.COM";     /* may need to change this */
  _AX = 0x4B00,
  geninterrupt( 0x21 );
}

void main( void )
{ puts( "  TINY SHELL DEMONSTRATOR\n" );
  puts( "Copyright 1990  by Jim Kyle\n" ),
  puts( "  Commands: DIR, RUN only\n" );
  for( ; ; )
    { printf( "tinyshell> "),
      gets(cmdbuf);
      for(i=0; i<2; i++)
        if(strnicmp(cmdlist[i],cmdbuf,strlen(cmdlist[i]))==0)
          break,
      switch(i)
      { case 0: do_dir();
                break;
        case 1: do_run(),
```

```
                break;
        default: puts("Unknown command!\n");
        }
    }
}
```

Of course, this shows just the bare rudiments of a DOS command interpreter. A real one would have to handle INT 23h (Ctrl-C) and INT 24h (Critical Error) at the very minimum. It also would be expected to take over undocumented INT 2Eh discussed later in this chapter, even if only to point it at an IRET instruction. What else might be possible to stumble through these things at a bare bones level is also (thankfully) beyond the scope of this bare bones program. COMMAND.COM for DOS 5.0, when disassembled, generates 388 pages of listing, at least half of that handles errors!

Unlike the other programs in this chapter, ISHELL.C is written to be compiled with only Borland C++'s command-line compiler. The interface to the DOS EXEC function in this program cannot be used in any environment being established by Microsoft's COMMAND.COM (or Quarterdeck's DESQview), and the library functions provided by Microsoft and Borland products do use the environment.

The communication between the command interpreter and the environment variables can be most easily discussed as a matter of conventions. The normal command interpreters allow you to modify the prompt and to specify a search path through which any program can spawn a copy of the interpreter. Both functions are accomplished by storing ASCII text strings in environment variables named PROMPT and COMSPEC. Similarly, you can specify the path to be searched for external commands, and they are stored in the PATH environment variable. COMMAND.COM and other command interpreters then obtain the information from these variables in the environment. But as shown in ISHELL, there's not really any necessary connection between the command interpreter and the environment; it's all a matter of convenience and convention.

Note that ISHELL is not intended to be useful for any purpose. Its sole purpose is to present the skeleton of a command interpreter. It recognizes only two commands, DIR and RUN. The RUN command actually launches COMMAND.COM as a child process in order to make the conventional DOS command set available. Without this capability, it's much more difficult to get ISHELL out of your system once you've tried it out!

Once you have ISHELL.COM and a batch such as the following in your CONFIG.SYS file (temporarily REM out any existing SHELL= statement

```
SHELL=C:\ISHELL.COM
```

Note that you must use the SHELL= command in CONFIG.SYS to install a different command interpreter. Many people are under the impression that a new shell can also be installed by changing the COMSPEC variable in the environment. The COMSPEC environment variable is used only after a command interpreter is already in memory. Until a command interpreter is loaded and initialized, neither the COMSPEC variable nor the master environment block itself exists!

Now reboot the system. You should see the prompt is now I'm-shell- rather than anything you may be used to seeing. You'll find also that the AUTOEXEC.BAT did not run and none of your TSR programs have been installed.

If you type DIR, you get a list of files in the current directory, but no subdirectories will be shown, nor will the amount of available space. Any other conventional command produces only an error message because ISHELL does not recognize it.

When you type RUN, you have all normal commands available to you, which lets you run an editor to change CONFIG.SYS back to get rid of the SHELL=ISHELL line.

ISHELL doesn't create a master environment block. You can verify the absence of a master environment by executing the ENVSEG.EXE program presented later in this chapter, from the child COMMAND.COM spawned by ISHELL's RUN. It shows no master environment, and SET shows that

PATH= is found on the current copy. The lack of an environment is intentional in order to demonstrate the independence of the interpreter from the environment in principle.

The key point about TSHELL though is the skeletal structure of a command interpreter provided in main(). This structure includes an endless but loop-controlled routine prompt, a more complete implementation that uses the environment could interpret and print getenv("PROMPT"), gets commands, interprets them, and executes them. That's all a command interpreter does.

How COMMAND.COM Works

This section is based on the disassembly of several versions of COMMAND.COM, the major emphasis is on those points not already adequately covered in other system documentation. This section also describes such terms as master environment and primary shell.

Although COMMAND.COM is not the only possible command interpreter, later in this chapter we look briefly at some alternatives. It is the one most used with MS-DOS because it comes as part of the system package. It contains code for the operating system because the real system files are hidden from view. Actually, in IBM's version of DOS 2.x, COMMAND.COM was an essential part of the operating system; the DOS EXEC function 4Bh was contained in COMMAND.COM rather than in the DOS kernel. By the time the Microsoft OEM versions were released, however, EXEC had been moved to its proper location, and the operating system itself became independent of COMMAND.COM.

The process of creating the primary shell actually begins when IBMBIO.COM in PC-DOS or IO.SYS in MS-DOS reads and the initialization code takes over. After a bit of preliminary housekeeping, IO.SYS moves the part of itself that has not yet been executed up to the topmost memory area previously protected by the HIDOS=DOS command. The process is similar to the way the DEVLOAD program in Chapter 7 was used to load device drivers.

From the system point of view, the IO.SYS code that installs the rest of the DOS kernel is probably responsible for the primary shell's access to the DOS services. Both modules load the first time for DOS's use. IO.SYS then creates a data PSP for its upper memory copy, making possible the use of handle-based DOS functions. Then the initialization code of device drivers, despite warnings to the contrary in the documentation, can use the low-number DOS functions and a few others are available. My thanks to Hans Steinberg, creator of BOOTSYS, for explaining this. It's still not clear though what happens to the memory at this point because the MS-DOS 6 manual in Chapter 7 was not yet been built.

The CONFIG.SYS file defines the primary shell's default name as COMMAND.COM at no SHELL= parameters. IO.SYS reads CONFIG.SYS, finds the primary shell's name, and then, with the help of its initialization routines, loads the MSDOS.SYS module. Control is then transferred to MSDOS.SYS, which takes control. After building all required data structures, the IO.SYS initialization module executes INT 21h function 4B00h to load and execute the primary shell program. Each primary shell has its own copies of the command interpreter's code and data. Control follows the COMMAND.COM segment:0 pointer to find its own parent using the PSP. Very soon now we'll take you through this keyboard lookup, however, after this is done.

One of the parameters passed to DOS with this request is the address of the associated environment block for the primary shell. A master environment block just above the DOS kernel area is assigned by default to the COMMAND.COM initialization routines. The size of this block defaults to 160 bytes but can be expanded by adding the /E:n option switch to a SHELL=COMMAND.COM /P line in CONFIG.SYS.

For parents other than COMMAND.COM, the exact method may differ, but all provide methods for inheriting, discovering the master environment, or whatever you need.

[illegible] DOS prior to 6.0 at the primary shell ever returned control to the IO.SYS initialization code. It was assumed that a fatal error, such as the stack becoming corrupted or critical system [illegible] had occurred and that continued operation would be impossible. [illegible] was followed by a dynamic halt [HALT.SYS], which would lock the [illegible]. Only pressing the reset button or power switch or powering down and then back up again could return the system to operation.

[illegible] could gain control was when the primary shell was loading. [illegible] specified a command for CONFIG.SYS [illegible] a move of the program to some directory [illegible] CONFIG.SYS could cause this failure. It has happened with DOS 5.0 or before. You needed to have a bootable floppy handy to bring the system back up so that you could correct the errors in CONFIG.SYS.

With version 6.0, however, [illegible] is replaced by a prompt that asks for the name of the command interpreter. The program then tries to load using the name you supply. If that attempt fails, the prompt appears again. This process continues until you give up and use a bootable floppy or until you succeed in establishing a primary shell.

[illegible] program executes, the area at the top of DOS RAM from which IO.SYS [illegible] becomes available for reuse. Subsequent operations while uninitializing the primary [illegible] overwrite the INIT code and the INIT.SYS which follows it.

Why Shells Are Their Own Parents

[illegible] asked me last year to explain why COMMAND.COM is always its own parent. Time, but I promised to explain why COMMAND.COM is always its own parent for the very good reason that I didn't know. Now, one of the first editions appeared. D. Rifkind posted an excellent explanation on the DVJ forum. What follows is based on his message.

One of the standard features of COMMAND.COM and of any other command interpreter shell [illegible] is to comply as completely as possible with accepted standards. That is, that the program contains the [illegible] Ctrl-C, Ctrl-Break, critical error interrupts, Abort, Retry, Ignore, and so on. One option this handling [illegible] is to allow a child process to inherit the parent's interrupt vectors. This means that if you are executing an external command that process is unceremoniously terminated.

[illegible] program does this when executing an external DOS command. The program [illegible] COMMAND.COM [illegible] shell is running. Because the shell must continue [illegible] INT 24 handler knows that COMMAND.COM is running and does something other than abort if you press A, right?

[illegible] does nothing different regardless of the process that [illegible] press I, the interpreter receives a code of 2, and DOS terminates the current [illegible] So why is it that COMMAND.COM gets away changing the system [illegible]?

[illegible] DOS [illegible] process, it uses the parent PSP field in that process's PSP [illegible] to determine which process is going to get [illegible] PSP is the same as the current PSP, however, DOS does not deallocate the [illegible] COMMAND.COM and all compatible shell programs sets the [illegible] PSP [illegible] points the termination address back into itself. The result [illegible] DOS [illegible] process, the current program stays active and retains control.

And that's why COMMAND.COM's parent PSP field points to itself. My grateful thanks to D. Rifkind for clearing this up!

How and Why COMMAND.COM Reloads Itself

One of the least understood parts of COMMAND.COM's internal operations is the reloading of the transient portion of COMMAND.COM [illegible] an external command. If something goes wrong in this process, the error messages can be [illegible] misleading. "Bad or missing command interpreter" when it was working fine just a second or two before is downright misleading. "Unable to

load COMMAND.COM when the real problem was that the COMSPEC variable pointed to a different version of the program. And a point that's usually unclear is why the reloading happens sometimes, but not always.

Whenever an external command is loaded, the RAM occupied by the transient portion of COMMAND.COM is made available to that external command for its use. Then, upon return from an external command, the resident portion of COMMAND.COM does a checksum of the transient area to detect any changes in it.

If any change has occurred, the resident routine reloads the entire transient area from disk, using the COMSPEC environment variable to locate COMMAND.COM. Only the copy part of this file is loaded. The exact offset into the file at which the reload begins is handled correctly by that portion of the resident that performs the reloading; this offset varies from one DOS version to the next.

The checksum for the transient portion is first calculated immediately after the program is through RAM. That result is stored in the resident portion. Later, after the checksum is recalculated, the new result is compared to the original value. Any mismatch causes the transient area to be reloaded. Thus it's essential that the copy of COMMAND.COM pointed to by the COMSPEC variable be identical, byte for byte, to the copy used at boot time.

After the transient area is reloaded from disk, the checksum is run again to verify that the reload was in fact successful. Any mismatch at this time triggers a terse DOS error message: Unable to load COMMAND.COM, system halted. And the computer must be rebooted. (Or, with DOS 5, this message eventually terminates only the pathset to COMSPEC; a reboot isn't necessary.) This message can also be triggered by differences between the copy of COMMAND.COM you're through COMSPEC and the copy from which the checksum was calculated at boot time.

Such differences are most often caused by having mixed versions of COMMAND.COM on the system (that is, having version 5 on the boot drive but version 4 on the floppy from which the system was started). Those problems may also be caused by patches applied to the disk-resident copy, which causes this program the reload needed to reset the system. Clearing the RAM copy of the checksum value also forces the parameters to be calculated.

Another possible cause of the reload error that you're faced with is the message that occurs in network situations when the network software redefines COMSPEC to point to the location of your COMMAND.COM. This copy was first from the copy that gives a workstation its boot error message. The way to avoid errors resulting from this problem is to remove the redefinition of COMSPEC from the network software, if possible. If redefinition is not possible, each workstation must be instructed to perform the network logon. That batch file must set up COMSPEC to point back to the workstation's own copy.

The Division Points

When first loaded by the initialization code in DOS's COMMAND.COM, the program divides itself into three parts. One part stays where it initially loaded—in low memory, just above the area where application programs run. Another part moves to the highest available area of conventional memory—the so-called DOS RAM. But the middle portion is discarded after it finishes setting things up. Official DOS manuals distributed with early OEM versions of the system told us that much. But there's more of the story.

Resident, Initial, and Transient Portions The three parts into which COMMAND.COM divides itself are known as the *resident*, *transient*, and *initialization* portions.

The resident portion of COMMAND.COM contains the interrupt service routines for INT 22h, which is really the interpreter of the interpreter, or a separate ISR. In some older versions of DOS it also contains some of the INT 21h service routines, including the one that handles the EXEC function. In addition to these interrupt handlers, the resident portion contains the routine that, when a terminated process returns control using the INT 22 pointer in the PSP, this portion also contains

some permanent data storage associated with the command interpreter such as the pointers to the transient portion

The transient portion is needed only for internal commands. For all others it is freed up for use by a program. The command.com file in the \dos directory contains the actual input buffer, the code that interprets commands, the internal command list, and all of the code for executing commands. In DOS 5.0 and higher, if DOS is loaded in the HMA, COMMAND.COM automatically puts much of the transient portion in extended HMA rather than at the top of conventional RAM.

Because the actual DOS input buffer is in the transient portion, the standard input editing commands such as F3 sometimes lose their data if the transient portion is overlaid during the processing of an external command. We'll take another small side trip to look inside DOS function 0Ah and see why this happens before we move on to study the environment. Right now, though, let's continue with the three portions of COMMAND.COM.

Nonresident initialization portion. Each time COMMAND.COM is loaded, at least some of this code is executed. It checks the version number of COMMAND.COM and the resident DOS kernel, itself, makes sure it can parse the arguments passed to the program. Other actions depend on whether the /P option was one of the arguments passed. If this switch is absent, the actions described in the next two paragraphs are skipped.

If /P was present, it's assumed that this is the primary shell being installed by DOS. AUTOEXEC.BAT is executed, and it sets the starting address for the transient portion. It moves the transient portion to the very top of RAM, determines and stores its checksum for future use in reloading, and sets up the interrupt vector for INT 2Eh to point to the INR inside the resident portion. Note that this second call makes the copy of COMMAND.COM the primary shell even if another copy already exists.

The initialization code then looks for the existence of a file named AUTOEXEC.BAT in the current working directory. If it exists, the initialization portion sets flags that direct the input routines to process this file before looking for keyboard input.

Regardless of COMMAND.COM determines its RAM allocation to be just adequate for cover the resident portion. However, if COMMAND.COM is not the primary shell (that is the one to which the INT 2Eh vector points), the resident portion refers to the copy and not to the primary copy. Each COMMAND.COM then passes control to the command input prompting routine. This routine issues the prompt, waits for input, and dispatches it, but the initialization portion, as such, ceased to exist when the RAM allocation was reduced.

Where These Portions Are Loaded The preceding descriptions show you how COMMAND.COM gets itself set up for action. In the first edition of this book, I provided detailed instructions for using a debugger to examine COMMAND.COM the way the various parts wind up at your own system. As you'll see in Chapter 6, DOS 5.0 becomes more complex. There are just too many possible variations, depending on whether you have DOS loaded high or low, whether you have UMBs enabled, and what model of CPU you have.

For instance, COMMAND.COM is now reentrant. I could write and author a forthcoming book on DOS internals. Part of COMMAND.COM contains a portion of sharable code, reentrant and processor independent. This code is loaded high and processed when a calling point table. You use INT 2Fh function 5500h to get the table address.

```
INT 2Fh     AX = 5500h
returns     AX = 0000h
            DS:SI = address of calling point table
```

The procedures used for this sharable portion include services provided for the transient portion, as well as interrupt handlers for int 23h, 24h, 2Eh, 2Fh. For the most part, the procedures manipulate data in the

COMMAND.COM resident portion. Because of this and the fact that the interval by which the dispatcher communicates its data segment is susceptible to change, these procedures must be of only limited use outside of COMMAND.COM itself.

In the first releases of DOS 5.0, they were called from a dispatcher in COMMAND.COM's resident portion. The dispatcher was unreasonably non-reentrant. Its structure is something like this:

```
int_23h:
                push    ax
                mov     ax,0
                jmp     get_address
int_24h:
                push    ax
                mov     ax,1
                jmp     get_address

                .
                .
get_address:
                sti
                mov     cs:[bx_save3],bx        << DANGER!!
```

BX was then used to index into the table of calling addresses. This opened a window for disaster each time COMMAND.COM loaded an interrupt because subsequent passage through the dispatcher could overwrite the saved value of BX which the first interrupt still needed. This would be serious if INTs 24h were followed a few microseconds later by an INT 21h or when one INT 21h interrupted another.

Later copies of DOS 5.0, when disassembled, show that this technique was repaired by individual preps for each ISR. The table still exists, but it contains far jumps that can take control directly into the DMA with no window for disaster en route. Access is direct, rather than by the old array indexing technique.

Why Does F3 Sometimes Quit Working?

A few pages back, I promised another side trip to discover why the standard input editing keys such as F3 occasionally and unpredictably quit working after a large external program is run. The scanning function is a critical part of DOS itself. It is invoked by Function 0Ah, buffered input. But there is more to its internals than is immediately connected with the way that COMMAND.COM partitions and reloads itself, so it's not too much of a digression to examine it here.

As you have seen, COMMAND.COM spends much of its time parked inside INT 21 0Ah. In order for the function keyed to the operations to work, Function 0Ah must first get all keyboard input into a temporary buffer. The function can't copy the input to the user's own buffer only after input is complete, since the temporary buffer is located on the user's stack, soon vanishes when Function 0Ah returns. To be able to use F3 to recover the input that was just typed, there must be another copy of that line in another temporary buffer maintained by Function 0Ah.

It is tempting to jump to the conclusion that this previous command is kept in the DOS data area, but that's not the case. Each application that supports the F3 editing capability must keep its own copy of "last input" data so that input for various applications won't be mixed up. For instance, you can go into DEBUG, or type "debug" on the DOS command line in DEBUG, you can use F3 to recall each line you type there, but when you return to the command shell prompt and press F3, the last DOS command line, "debug," shows up. It has been saved by COMMAND.COM itself all the time you were using DEBUG.

Incidentally, the official documentation for Function 0Ah is strangely silent on just how the DOS editing functions are brought into play. In fact, the *MS-DOS Programmer's Reference* for DOS

3.0 calls Function 0Ah "obsolete" and recommends using Function 3Fh instead although the Read File function used has no editing capabilities at all. It appears, though I have been unable to confirm this in the copy of 4.0 available to me, that the Read File function detects reading from STDIN as a special case and really uses the Function 0Ah code.

The function context requirement for using Function 0Ah is that DS:DX point to a buffer large enough to accept the expected input, starting at its third byte. The first byte of the buffer specifies the maximum number of bytes it can hold, and the second byte the number of bytes now in the buffer. Normally most programs set the second byte to zero when setting up the buffer.

It turns out that this buffer itself serves dual duties as the "last copy" and as the destination for new input. Several requirements must be met in order to enable function key editing with Function 0Ah; the standard assembly language program at Figure 10-5, F3TEST.ASM, shows them all.

Figure 10-5. F3TEST.ASM

```
        title   F3TEST
.model small                            ; use simplified seg style

.data
buf1    db      126,0                   ; buffer for input
        db      126 dup (0)
buf2    db      'This is Buf1 initial string'
buf2l   equ     $ - buf2                ; calculated data length
crlf    db      13,10,'$'
buf3    db      128 dup (0)             ; buffer for output

 stack

 code
start   proc
        mov     ax, DGROUP              ; set up segment regs
        mov     ds,ax
        mov     es,ax
        mov     di, offset DGROUP buf1  ; prepare to preload buffer
        mov     si, offset DGROUP buf2

        mov     cx,buf2l                , get the move count
        mov     al,126                  , establish max size
        mov     ah,cl                   , and current size (essential)
        stosw
        inc     cx                      , include the CR in data moved
        rep movsb

LT:     mov     dl,'*'                  ; prompt character
        mov     ah,2
        int     21h
        mov     dx, offset DGROUP buf1  , get buffered input line
        mov     ah,0Ah
        int     21h
        mov     al,buf1+1               ; check returned length
        cmp     al,1
        jb      L2                      ; quit if zero

        mov     si,offset DGROUP buf1+2 , copy to Buf3 for output
        mov     di,offset DGROUP buf3   , (essential that BUF1
        xor     cx,cx                   ;  not be changed in any
        mov     cl,al                   ,  way, to allow edits)
        rep     movsb
        mov     si, offset DGROUP crlf  , append CR/LF/$
        mov     cl,3
        rep     movsb
        mov     dx, offset DGROUP:crlf  , print CR/LF first
        mov     ah,9
```

```
        int     21h
        mov     dx,offset DGROUP.buf3   ; then print BUF3
        mov     ah,9
        int     21h
        jmp     L1                      ; go back for another

L2:     mov     ax,4c00h                ; terminate process
        int     21h

start   endp

        end     start
```

When you assemble and link this program, then run it, you can press F3 as the initial response to the prompt and see the preloaded data string that was moved into the input buffer by the code immediately ahead of label L1.

The essential point here is that the length byte at BUF1 must point to an ASCII CR character in order to enable the function key editing feature. Also the input buffer must either be preserved without change or be restored to the same condition in which function 0Ah set it up, in order to permit subsequent calls. That's why F3 [ENTER] copies the input line over to buffer BUF3 before appending the CR and EL to terminate the input loop. It's also why the two bytes at BUF3 and BUF4 are not modified inside the loop but are left just as they were returned by the previous call to function 0Ah. Simple enough, but it took a while to discover that these were essential to enable the edit capability.

Here's a short sample to show how it works:

```
D:\DOS2\CHAP10>f3test
:This is Buff1 initial string
This is Buff1 initial string
 NEW---s Buff1 initial string
NEW---s Buff1 initial string
!

D:\DOS2\CHAP10>
```

On the second run, I simply pressed F3 to echo out the preloaded initial string. Then I pressed [ENTER] [F3] [ENTER] to echo out the buffer contents back and then prompted me again. This time I typed "NEW" and then pressed F3 followed by [ENTER].

The reason why the editing functions fail when the transient portion of COMMAND.COM is overlaid by a large program is simple: it's the last input buffer kept by COMMAND.COM. Actually, the working buffer that it uses for parsing the command line is located in the transient portion. The permanent copy of this buffer exists in the nontransient portion of COMMAND.COM. Thus when you press F3 or one of the other editing keys after the transient portion has been reloaded from disk, you get only the empty buffer instead of the actual last input data.

DOSKEY

The DOSKEY TSR that comes with DOS provides a command history capability that allows you to recall and to some previously entered command lines, edit them, and supply them to COMMAND.COM in place of input from the keyboard.

As you saw at the start of this chapter when tracing one cycle of COMMAND.COM's operating loop, the shell first checks DOSKEY by means of INT 2Fh to determine that it's installed and, at the same time, to ascertain its segment if DOSKEY is active. Only if DOSKEY is not active does COMMAND.COM call INT 21/0Ah.

DOSKEY maintains a ring-linked collection of input buffers. Each time that DOSKEY is called, it takes the next buffer in the ring, clears its character count to zero, and calls INT 21/0Ah to get input into that buffer.

Up- and down-arrow keys select either a previous or later buffer from the ring, without clearing the current buffer. This allows you access to any buffer in the collection by repeated use of either arrow key. Input buffers are not automatically stepped when stepping in either direction.

When stepping to input characters, DOSKEY issues the same INT 28h as INT 21h AH=0Ah would.

Using the Environment

This section discusses the environment as implemented by MS-DOS and used by COMMAND.COM. Although the environment itself is purely based at the operating system level (the PSP contains an environment segment field, for instance), the details of its usage are left to the command interpreter, with the result that this discussion may not apply fully if an alternate interpreter is used.

How COMMAND.COM Uses the Environment The idea of an environment for each process (and inheritance of the master environment) came to MS-DOS from UNIX, but was greatly simplified in the transfer. As currently implemented in MS-DOS, the environment consists of a paragraph-aligned block of space that can be up to 32,767 bytes in length, although in practice it is always much smaller. This block contains a collection of environment variables, each of which consists of a variable name followed by the value to be assigned to that variable. Both the name and the data are stored as an ASCIIZ text string, with an equal sign separating the name from the data. Note that this is just the convention used by COMMAND.COM; it is not something built into DOS itself.

DOS provides two methods for creating a process and its environment. DOS plugs the segment address of the environment into the word at offset 2Ch of the PSP when DOS dispatches the process through DOS EXEC (INT 21 4Bh).

The program that calls EXEC is responsible for allocating the environment space and defining all the variables and their values that are to be passed. If the segment address passed to the DOS EXEC function is 0000, DOS will duplicate as much space as it contains a copy of each variable in the caller's environment and assign the copy to the child process. The undocumented, except for DOS 4.x, DOS EXEC environment space used internally by the primary shell must be set up explicitly by the primary shell itself when it initializes. Otherwise, no master copy of the environment will exist.

COMMAND.COM uses several predefined environment variables to control its actions. COMSPEC provides the drive, path, and file specification that is used each time COMMAND.COM must reload its transient portion. PATH lists the directories to be searched for possible external commands. PROMPT defines the string of characters that COMMAND.COM uses to prompt for user input.

Both PATH and PROMPT have separate internal commands that can be used to modify their values. However, any environment variable can be modified by the internal command SET. If the variable does not exist, it is created, provided that enough space exists for it from the primary environment space. The SET command operates on the master environment.

The predefined environment variables PATH and COMSPEC only are created in the master environment by the primary shell's own initialization code. The size of the master environment is established at this time (160 bytes by default, but can be altered by the /E:*nnnn* option in the SHELL=COMMAND.COM line in CONFIG.SYS). Alternate shells use different syntax but have the same capability.

Once the primary shell has been loaded, its environment space allocation cannot be increased. While it might appear simple to replace it with a new, larger copy and adjust the segment address at

PSP:002C. Second, that original master environment address was also saved in undocumented internal locations for use by internal commands. Those addresses would be difficult to locate and alter in order to modify them.

When COMMAND.COM dispatches an external command, it simply passes the file back to DOS, thus generating an exact copy of the master environment for use by the spawned process. Because it is a copy and not the original, any changes made to it by the process will not be reflected in the master environment itself. Although this protects the master environment from being altered accidentally, it is difficult to alter it intentionally except by using the SET command from the primary shell command line prompt, which is not always convenient.

Locating the Environment Before you can make any use of the information stored in the environment area, you must first locate it. DOS stores the segment address of the environment area for each process in the word at offset 2C hex in the PSP, but if you need access to the master environment you must locate the PSP for the primary shell.

The assembly language package shown in Figure 10-6, ENVPKG.ASM, contains three routines designed to support small model C programs. Curenvp and mstenvp locate the current and the master environment areas, respectively, and return far pointers to the first byte. envsiz accepts as input a pointer such as the one returned by the first two and returns the size of the area in paragraphs.

Figure 10-6. ENVPKG.ASM

```
;ENVPKG.ASM   Jim Kyle - July 1990, April 1993

.model small,c

 data
; assumes being used from C with _psp global variable
        extrn   _psp:word

.code

curenvp proc
        public  curenvp
; char far * curenvp( void );
        mov     ax,_psp         ; get PSP seg
        mov     es,ax
        mov     dx,es:[002Ch]   ; get env address
        xor     ax,ax           ; offset is zero
        ret
curenvp endp

mstenvp proc
        public  mstenvp
; char far * mstenvp( void );
; This is the only guaranteed method for COMMAND.COM if DOS=HIGH is
; in effect, but has problems under some circumstances
; See notes in text
        mov     ax,352Eh        ; get INT2E vector
        int     21h             ; vector in ES:BX
        mov     dx,es:[002Ch]   ; es:2C is seg of environment
        xor     ax,ax           ; make the offset zero
        ret
mstenvp endp

envsiz  proc    oenv:word, senv:word
        public  envsiz
; short envsiz( char far * vptr);
        mov     ax,senv         ; get segment of env
        dec     ax              ; back up to MCB
```

```
        mov     es,ax
        mov     ax,es:[0003h]   ; get size in paragraphs
        ret
envsiz  endp

        end
```

The comment lines following each of the *public* directives are simple prototype declarations to be used by programs that access ENVPKG. To use these routines, first assemble the program into an OBJ file as follows:

```
MASM /mx ENVPKG;
TASM /mx /jMASM51 ENVPKG;
```

The /mx option on both assemblers forces procedure names to remain in lower case so that the OBJ file works with case-sensitive C programs. The operation of curenvp() and mstenvp() also relies on the small memory model for the PC, in which far pointers to the DX:AX register pair.

The envsiz() procedure assumes an external global variable called _psp. This variable is provided in all C compilers for the PC, although some compilers declare _psp in DOS.H and others in NTDDI.H. You could easily modify the code to call either INT 21 ;51h or INT 21 ;62h if you prefer to avoid compiler differences.

The envsiz() routine is based on the fact that every environment block starts at an offset of zero and immediately follows a Memory Control block that contains the size of the block in paragraphs. So envsiz() uses whatever pointer is the environment block to envsiz() decrements it by one paragraph, and then accesses the MCB and then retrieves the size from offset 3 in that segment. Note that the size is stored as paragraphs. If a byte size is needed, the returned value must be multiplied by 16 (shifted left 4 places).

The short C program EPTST.C, shown in Figure 10-7, uses the ENVPKG routines. Compile this test, using the small memory model and link with ENVPKG.OBJ:

Figure 10-7 EPTST.C

```
/*************************************************************
 *  EPTST.C   tests environment-access object modules        *
 *  Jim Kyle, July 1, 1990, April 1993                       *
 *************************************************************/
#include <stdio.h>

char far * curenvp( void );   /* prototype declarations   */
char far * mstenvp( void );
short envsiz( char far * vptr);

void main (void)
{ char far *mine,
  char far *master

  puts("\nEnvironment locations:");
  mine = curenvp();
  master = mstenvp();
  printf( "Current environment is at %Fp, size: %i bytes\n",
          mine, envsiz(mine)<<4 );
  printf( "Master environment is at %Fp, size: %i bytes\n",
          master, envsiz(master)<<4 );
}
```

Typical output from EPTST, when run at the primary shell's command prompt, follows:

```
Environment locations:
Current environment is at 1868:0000, size: 256 bytes
Master environment is at 1107:0000, size: 512 bytes
```

This shows how the current working copy of the environment has been trimmed to a size just adequate to hold the defined variable strings and the program's pathspec.

Other Ways of Locating the Environment The preceding discussion has a problem which does not often arise but is serious when it does. The interrupt vector for INT 21h doesn't always point to the primary copy of the command interpreter. For example, using DirectMasters INTRSPY program from Chapter 5, it's trivial to take over INT 21h for the purpose of setting a breakpoint. If INTRSPY comes along while INTRSPY is in control of INT 21h, it will think that INTRSPY is the primary command interpreter, even though INTRSPY has simply hooked INT 21h for diagnostic purposes and is just chaining the interrupt to the previous owner, presumably the primary command interpreter.

Of course, this is unlikely to happen out in the field. After all, nothing but a command interpreter really takes over INT 21h right? Still, it's easy to fool instead of to correctly find once one knows how to do so.

What other ways are there of locating the master environment?

One technique avoids the issue of locating the master environment entirely. It issues INT 21h commands using INT 2Eh. The ability to call COMMAND.COM using INT 21h is discussed later in this chapter. Note that instead does not call INT 21h at all; merely uses an interrupt vector in hopes of finding the primary command interpreter. This technique is repeated in instead to MSTENVP.C below.

As to the different technique used by the BAT compiler discussed earlier in this chapter, it walks the MCB chain looking for the environment segment belonging to the primary command interpreter. Chapter 7 documented how to walk the MCB chain. The key here is to take the first environment you find in the chain.

How do you find the first environment? Don't look for certain ASCII characters to see if an MCB corresponds to an environment; instead, look for PSPs. Walk the PSP chain as I've described and look at offset 2Ch. Take the first environment you find. How do you know you've got a PSP? Look for the opcode bytes for INT 20h. (The 20h is like some preassigned magic number.) Look for an MCB whose owner is one greater than its MCB's seg. See the function instemp2 in Figure 10-8.

Another technique, designed especially to accommodate command interpreters, deals with the problem also. It walks the MCB chain from the top, looking for the last environment that is at a higher address than its corresponding PSP. Here's a question: Why look for the last environment? Because of the program and you look for an environment higher than its PSP, or at least the command interpreter builds an environment for itself. Therefore, the environment is at a higher address than the program. See instemp3 in Figure 10-8. Note that this technique can easily fail if you load programs into UMBs since some of the memory manager routines load and place the environments *after* the program rather than before, when loading high. It also fails if you use 4DOS and have it swap itself into a UMB.

I call another technique involves walking back along the PSP chain until you find a PSP that is its own parent. However, this technique, which first appeared in Barry Simon's "Providing Program Access to the Real DOS Environment," PC Magazine, 28 November 1989, pp. 309–314, is designed to find what's called the active environment, not the master environment. This matters only if the current active shell is a program spawned from the SHELL statement in CONFIG.SYS. If you're within a program spawned from the SHELL statement and you run FoxPro, for example, you want to find the master environment, using this technique.

On the other hand, there's the only reliable way to locate the effective master environment if you are running in a DOS box from Windows since each DOS box gets its very own copy of the master environment. For example, ENVEDIT, as presented in our first edition, didn't work in a DOS box under Windows. It affected the wrong environment, one too high up in the chain. We've revised ENVEDIT to overcome this problem in the current version.

...three techniques for finding the master environment appear in the routine in Figure 10-8. The function walk() in MSTENVPC.C is a variation on the UDMEMC program from Chapter 7. Here, the walk() function expects a pointer to a function. For each MCB it finds, walk() calls this function, passing it an MCB pointer. The function should return TRUE to indicate that walk() should keep going, or FALSE, to indicate that walk() should stop.

...how to write different functions to plug into walk(), making MSTENVPC (Figure 10-8) a test bed for trying out different methods for locating the master environment using the MCB chain.

Figure 10-8. MSTENVP.C

```
/*
 * MSTENVP.C
 * test bed for different methods to find master environment
 * Andrew Schulman, July 1990
 * modified July 1992 to use  undocdos.h  typedefs
 *          and also for UMB support - Jim Kyle
 */

#include <stdlib.h>
#include <dos.h>
#include "undocdos.h"                                   /* see Chapter 7 */

extern LPMCB firstblk( void );

/*****************************************************************/
LPMCB get_mcb(void)             /* returns far pointer to first MCB */
{   _ASM mov ah, 52h
    _ASM int 21h
    _ASM mov dx, es:[bx-2]
    _ASM xor ax, ax
}       /* in both Microsoft C and Turbo C, far* returned in DX:AX */

char far *env(LPMCB mcb)         /* returns far ptr to env, or NULL */
{   char far *e;
    unsigned env_mcb;
    unsigned env_owner;

    if (! IS_PSP(mcb))
        return (char far *) 0L;

    e = MK_FP(ENV_FM_PSP(mcb->owner), 0);
    env_mcb = MCB_FM_SEG(FP_SEG(e));
    env_owner = ((MCB far *) MK_FP(env_mcb, 0))->owner;
    return e;
}

typedef BOOL (*WALKFUNC)(LPMCB mcb);

/*  General purpose MCB walker
 *  The second parameter to walk() is a function that expects an
 *  MCB pointer, and that returns TRUE to indicate that walk()
 *  should keep going, and FALSE to indicate that walk() should
 *  stop.
 */
BOOL walk(LPMCB mcb, WALKFUNC walker)
{   for (;;)
        switch (mcb->type)
        {   case 'M':
                if (! walker(mcb))
                    return FALSE;
                mcb = (LPMCB)MK_FP(FP_SEG(mcb) + mcb->size + 1, 0);
                break;
            case 'Z':                           /* end of an MCB chain */
```

```
            walker(mcb);
            if( FP_SEG( mcb ) < 0xA000 )
              { mcb = firstHi(),          /* bridge to UMB chain */
                if( mcb == ( FP ) 0L )
                  return FALSE,                    /* none found */
              }
            else
              return FALSE,                 /* UMBs all done too */
            break;
        default:
            return FALSE;                 /* error in MCB chain? */
    }
}

/*************************************************************************/
/* using the GETVECT 2Eh technique (ENVPKG.ASM) */
void far *mstenvp1(void)
{   _ASM mov ax, 352eh                     /* get INT 2Eh vector */
    _ASM int 21h
    _ASM mov dx, es:[002Ch]                /* environment segment */
    _ASM xor ax, ax                      /* return far ptr in DX:AX */
}

/*************************************************************************/
/* walk MCB chain, looking for very first environment */
void far *env2 = (void far *) 0;

BOOL walk2(LPMCB mcb)
{   env2 = env(mcb);
    return env2 ? FALSE : TRUE;
}

void far *mstenvp2(void)
{   walk(get_mcb(), walk2);
    return env2;
}

/*************************************************************************/
/* walk MCB chain, looking for very LAST env addr > PSP addr */
void far *env3 = (void far *) 0;

#define NORMALIZE(fp)   (FP_SEG(fp) + (FP_OFF(fp) >> 4))

BOOL walk3(LPMCB mcb)
{   void far *fp;
    /* if env seg at greater address than PSP, then
       candidate for master env -- we'll take last */
    fp = env(mcb);
    if (fp)
        if (NORMALIZE(fp) > (FP_SEG(mcb)+1))
            env3 = fp;
    return TRUE;                  /* always return TRUE to get last */
}

void far *mstenvp3(void)
{   walk(get_mcb(), walk3);
    return env3;
}

/*************************************************************************/
/* walk MCB chain, looking for very first environment belonging
   to PSP which is its own parent */
void far *env4 = (void far *) 0;

BOOL walk4(LPMCB mcb)
```

```
{   env4 = env(mcb);
    if (env4)
    {   unsigned psp = FP_SEG(mcb) + 1;
        return (PARENT(psp) == psp) ? FALSE /*found it!*/ : TRUE;
    }
    else
        return TRUE;    /* keep going */
}

void far *mstenvp4(void)
{   walk(get_mcb(), walk4);
    return env4;
}

/*************************************************************************/
void main( void )
{   printf("GETVECT 2Eh method; mstenvp1   = %Fp\n", mstenvp1());
    printf("WALK MCB method, mstenvp2     = %Fp\n", mstenvp2());
    printf("WALK MCB/LAST method; mstenvp3 = %Fp\n", mstenvp3());
    printf("WALK MCB/OWN PARENT, mstenvp4  = %Fp\n", mstenvp4());
}
```

How does this program behave under various conditions? First let's try it from the normal COMMAND.COM prompt:

```
D:\UDOS2\CHAP10>mstenvp
GETVECT 2Eh method, mstenvp1   = 1A7B:0000
WALK MCB method, mstenvp2      = 1A7B:0000
WALK MCB/LAST method; mstenvp3 = 1A7B:0000
WALK MCB/OWN PARENT, mstenvp4  = 1A7B:0000
```

So far so good. All four methods agree on where the master environment is. Let's see what happens if we load a child copy of the command interpreter:

```
D:\UDOS2\CHAP10>mstenvp
GETVECT 2Eh method, mstenvp1     = 1A7B:0000
WALK MCB method, mstenvp2        = 1A7B:0000
WALK MCB/LAST method; mstenvp3 = 1B29:0000
WALK MCB/OWN PARENT, mstenvp4    = 1A7B:0000
```

Oh oh! The third method picked up the child copy's environment instead of the master's. But that might not always be bad because sometimes you need to be able to locate the active rather than the master copy.

Now let's load a new permanent command interpreter with the /p flag and run MSTENVP again:

```
D:\UDOS2\CHAP10>mstenvp
GETVECT 2Eh method; mstenvp1     = 1B29:0000
WALK MCB method; mstenvp2        = 1A7B:0000
WALK MCB/LAST method, mstenvp3 = 1B29:0000
WALK MCB/OWN PARENT, mstenvp4    = 1A7B:0000
```

Here mstenvp2 and mstenvp4 were in error. They both stuck with the old abandoned environment segment at 1A7B:0000 instead of getting it as the other two subroutines did. The /p flag in COMMAND.COM or any program (4DOS.COM or NDOS.COM) creates a new primary command interpreter and a secondary command interpreter. Strike one for mstenvp2 and mstenvp4.

What happens if you run a second child copy of the command interpreter under the new primary? By now you should be expecting to find at least three different environments, and you do:

```
D:\UDOS2\CHAP10>mstenvp
GETVECT 2Eh method; mstenvp1     = 1B29:0000
WALK MCB method, mstenvp2        = 1A7B:0000
WALK MCB/LAST method, mstenvp3 = 1BD7:0000
WALK MCB/OWN PARENT, mstenvp4    = 1A7B:0000
```

Only mstenvp1 succeeds because the real master environment is the last one. mstenvp3 grabbed the child copy just as it did earlier, while the other two techniques were still stuck on the original no longer valid, version.

After loading a debugger (INTERSPY, with an appropriate script that hooks INT 2Fh), we get this:

```
D:\UDOS2\CHAP10>mstenvp
GETVECT 2Eh method, mstenvp1    = F800:0000
WALK MCB method; mstenvp2       = 1A7B:0000
WALK MCB/LAST method; mstenvp3  = 1829:0000
WALK MCB/OWN PARENT, mstenvp4   = 1A7B:0000
```

Now, mstenvp1 is wrong, too. Segment F800 points into the debugger, not the primary command interpreter. Only mstenvp2 and mstenvp4 properly identified the master environment, and these too would have been wrong had a second primary been present.

Finally, reboot the machine, load a TSR in CONFIG.SYS with the INSTALL command, and try MSTENVP again:

```
D:\UDOS2\CHAP10>mstenvp
GETVECT 2Eh method, mstenvp1    = 1C35:0000
WALK MCB method, mstenvp2       = 1968:0000
WALK MCB/LAST method, mstenvp3  = 1C35:0000
WALK MCB/OWN PARENT, mstenvp4   = 1C35:0000
```

In this situation, mstenvp2 was wrong again. Segment 1968 points into the environment of the TSR loaded with the INSTALL command. This is an program that uses the "walk MCB" method of finding the master environment. This whenever a user (DOS 4.0 or higher) uses the handy INSTALL= command.

Could some other method be made to work? mstenvp2 is deleted this situation. Yes. Take not the first environment found, but the first environment belonging to a TSR that is its own parent (another possibility). Let's call this mstenvp4. Update to show off all the strategies.

This works beautifully for the DOS 4.0 and higher INSTALL situation, but as we saw earlier, test runs could leave the problem with a program that caused mstenvp2 to fail. It also fails miserably under Quarterdeck's 386MAX in conventional memory, which sometimes alters the unused fields of MCBs in Upper Memory Blocks. Even changes it makes are detailed in the UMBPMCB.ZIP file in Chapter 7. Even if master environment still appears to be loaded high under 386MAX, it won't usually be found by this technique.

All these methods failed when a command.com lower in the memory allocation strategy is set to load the top-level shell is loaded. In such a case, you may have to settle for finding the active environment rather than the master copy, by working back up the parent process chain, as shown in the RDOSENV program of Chapter 7 or in the section which follows.

This, although all these techniques work pretty well in many cases, none provides a 100 percent fool-proof method of finding the master environment. It's across the problem. I suggest. Here are the results of some limited tests on special cases, but trying to anticipate such cases is what distinguishes the professional programmer from the amateur. So what's a programmer to do? One technique, of course, is to perform the mstenvp4 function in two or more different ways, compare the results, and bail out if they don't match.

It's some small comfort that Microsoft itself messed up finding the master environment in its own APPEND at first, while APPEND /E switch when executed in a secondary command interpreter does not affect the master environment and can in fact cause system crashes. Other crashes may also be due to APPEND's interception of EOF open and get file size requests which corrupt register DX if the file is not actually found, a bug which Geoff Chappell notes has been present since at least DOS 3.30.

All of the examples here (by the way) were run with COMMAND.COM. Alternative command processors may drastically alter the results from the four search methods. For instance, while the /p switch to cause COMMAND.COM to create a new primary shell and effectively discard the original, the 4DOS alternative does not change the primary nor does it modify where the INT 2Eh vector points once the program has been loaded. In addition, its capability to put the environment in a UMB affects some of the search techniques. Thanks to Lewis Pape, who raised questions about these variations in the 4DOS support area of CompuServe. The questions prompted me to dig a bit deeper for good answers, which boil down to *use the active rather than the master environment in most use*.

Finding the "Active" Environment

When the four techniques for locating the master environment fail, it's time to walk back along the PSP chain until one finds a PSP which is its own parent. This technique was first described by Ray Santesson in the 28 November 1989 issue of *Microsoft*.

Let's see how to use this technique to revise our RODOS program back in Chapter 7. Here's a code fragment based on our revised version of ENVIDUP.C, which appears in full later in this chapter:

```
#include  "undocdos.h"                  // see Chapter 7
char far * FindActive( void )
{ WORD parent, self;
  self = _psp;                        // or use INT 21/62h
  parent = PARENT( self );
  do                                  // trace back up the chain
    { self = parent;
    }
  while (( parent = PARENT( self ) ) != self );
  return  (char far *)MK_FP( ENV_IN_PSP( parent ), 0 );
}
```

Walking back along the PSP chain always locates the currently active shell, that's what you need to do when running in a DOS box under Windows or OS/2. It's the wrong way to go, though, if you're writing a shell program or shell-replacement tool such as Norton's Commander. These programs spawn an isolated shell for each command, which then vanishes without trace upon returning to the menu or dispatcher. The active environment you find will be destroyed before you execute the next command when this happens.

Searching the Environment

Just locating the environment block, of course, isn't enough to let you search it for data. The next step is to know the format in which information is stored there and write some code that knows how to browse the items you want.

Environment storage format is wonderfully primitive. ASCII text. Each variable consists of a single ASCII string. The first part of the string is the variable's name and the rest is its data. The name and value are separated by an equal sign. The string is terminated C style with an all zero byte (the meaning of ASCII 0). Each variable is stored following the previous one, and the end of the list of variables is indicated by two consecutive all zero bytes.

Since version 3.1 of DOS, DOS has also stored another item of information in the environment that will help us specify to DOS the process that we want a copy of the environment. This information immediately follows the double zero bytes, and it begins with a binary (not ASCII) 01h word. That word indicates the number of strings that follow. The drive letter in ASCII appears as the next byte, and the pathspec in ASCII follows it. Then a zero byte terminates the string. Bytes reached.

Once you have that pointer to the first byte of the environment area and you know the internal storage format just described, it's simple to write code to locate an environment variable by name.

In fact, current C compilers include ready-to-use functions `getenv()` and `setenv()` to do just that, but they are limited to accessing only the current word's copy of the environment. What's more, many, if

not most implementations make still another UNIX style copy of the variables into their own data areas. This copy supports the optional envp argument to main.

For maximum flexibility you need to be able to access any copy you desire at any time. If you happen to be shelled out of a program, changes made to the current copy vanish without a trace when you return to the parent program. Changes made to the master copy remain, but they will have no effect until you return to the primary shell.

Several methods could be used to provide totally flexible access to the environment. The one we'll explore is designed for easy expansion to other needs. Its foundation is the small assembly language function shown in NXTEVAR.ASM (Figure 10-9). This function accepts as input a pointer to one environment variable. It returns either a pointer to the first byte of the following variable, which may be a null zero byte or NULL if the input pointer already points to a null zero byte.

Figure 10-9. NXTEVAR.ASM

```
;       NXTEVAR.ASM - Jim Kyle - July 1990

.model small,c
.code

nxtevar proc    uses di, vptr:far ptr byte

        public nxtevar
; char far * nxtevar( char far * vptr );
        les     di, vptr
        mov     cx, 8000h
        xor     ax, ax          ; search for 0 and...
        mov     dx, ax          ; ...initialize return DX:AX to 0:0
        repne   scasb           ; search ES:DI for char 0 in AL
        inc     cx              ; CX = 8000h if only one 0 found
        js      nev
        mov     dx, es
        mov     ax, di
nev:    ret
nxtevar endp
        end
```

This function is presented with a far pointer to an ASCIIZ string, not just one in the environment area. It returns a far pointer to the byte that follows the end of string marker byte. In the environment, this normally is either the first byte of the next string or to a byte that is all zeroes. In the latter event, the end of the environment's variable area has been reached, so another call to nxtevar using this pointer would return NULL.

Before you begin, the previous call to nxtevar will have returned the far pointer to the all zeroes word. If each pointer is examined in an array, the total can be used to process the program path name. Pointers that can be passed to a routine that just wants the next two bytes are 0001 and 0002. These point to path information from the scanning. Because the path data is the only variable that is ASCIIZ string, the normal C string functions deal with it properly.

This function is flexible because you can pass the function a pointer to any environment string, including the current one you've obtained with the corresponding function of ENVPKG, the master environment you obtain by using getenv, or one of the active environment which I used later shows how to obtain with the ENVEDIT.C program.

To use NXTEVAR.ASM you must assemble it into an OBJ file following the procedures noted earlier in this chapter for ENVPKG.ASM. To illustrate how NXTEVAR.ASM is used, Figure 10-10 shows a little C program that reports the location and contents of each string in the current environment.

Figure 10-10. NEV.C

```
/*********************************************************
 *  NEV.C - Next Environment Variable                    *
 *  Jim Kyle, July 1, 1990                               *
 *********************************************************/
#include <stdio.h>
#include <stdlib.h>

char far * nxtevar( char far * vptr );
char far * curenvp( void );

void main (void)
{ char far * myenv;

  myenv = curenvp();
  while ( myenv )
    { printf("Env Var at %Fp: %Fs\n", myenv, myenv );
      myenv = nxtevar( myenv );
    }
  exit(0);
}
```

To link to NEV.EXE from the C programs use either Microsoft or Borland C compilers, both the LNVPKG.OBJ and NXTEVAR.OBJ modules must be used this time because NEV.C calls curenvp() to locate the environment block. NEV.C calls nxtevar() to locate each variable string in the environment block, one after the other, in the sequence in which they occur in the environment block. More often, you'll want to locate a specific environment variable by name, and you may want to locate it in the master environment rather than in the current copy. You could use the library function getenv() to return a pointer to the named variable in the current environment copy, but getenv() won't access the master.

To both search by name and use the master environment, we modify NEV.C into a far more useful program, FMEV.C, as shown in Figure 10-11. This also requires LNVPKG and NXTEVAR.

Figure 10-11. FMEV.C

```
/*********************************************************
 *  FMEV.C - Find Master Environment Variable            *
 *  Jim Kyle, July 7, 1990                               *
 *********************************************************/
#include <stdio.h>
#include <stdlib.h>
#include <string.h>

char far * nxtevar( char far * vptr );
char far * mstenvp( void );

void main ( int argc, char * argv[] )
{ char far * menv;
  char vname[128], *vdata, tgt[64];
  int tlen;

  menv = mstenvp();
  if (argc < 2)
    { printf("Var to find: ");
      gets( tgt );
    }
  else
    strcpy( tgt, argv[1] );
  tlen = strlen( tgt );

  while ( menv )
```

```
    { sprintf(vname, "%Fs", menv );
      if ( vname[tlen] == '=' )
        { vdata = &vname[tlen+1],
          vname[tlen] = '\0',
          if ( stricmp( tgt, vname ) == 0 )
            break;
        }
      menv = nxtevar( menv );
    }

  if ( menv )
    { printf("Found %s at %Fp \n%Fs\n", vname, menv, vdata ),
      exit(0),
    }
  else
    { printf("%s not found.\n", tgt );
      exit(1);
    }
}
```

In EMEV the declaration of main( ) has been changed to permit the desired variable's name to be entered as a command line argument. Using sprintf( ) with the %Fs format specifier forces the library routine to do all necessary conversion to copy each string over from the environment to the local work area vname. Although fewer complex include files, the %Fs format code is somewhat awkward to use, giving tasks the sprintf( ) solution still seems much simpler to comprehend.

We'll return to the environment at the end of this chapter with the ENVIDD utility.

INT 2Eh, the Back Door

Interrupt 2Eh provides a back door into COMMAND.COM, allowing access to both the main interpreter routine and the command dispatcher from outside the program. Its entry is popular because this interrupt is not used by the command interpreter itself for any purpose. Unchecked.

The procedures to which INT 2Eh provides access, though, are not to entirely. The execution of batch files and the LOAD and EXEC functions come under these procedures. Consequently, an external program that calls INT 2Eh can be called a "batch job" program. It is important to note that this interrupt is serviced by code in the resident portion of COMMAND.COM itself, rather than by DOS. If an alternative command interpreter such as 4DOS is installed in place of COMMAND.COM, the description provided in this section will not be true.

Although INT 2Eh can be dangerous if used without knowing its limitations, it does grant access to the primary copy of the command interpreter, usually the one dispatched by CONFIG.SYS during system bootstrap.

The real meat on this weird aspect of undocumented DOS can be found in Daniel J. Greenberg's article "Recovering the DOS Shell," which appeared in *Programmer's Journal* May/June 1990 on pages 28–36. It's a must as the definitive piece on INT 2Eh. Unfortunately, *PJ* is no longer published, and copies of this source may be nearly impossible to locate.

The Function The purpose of INT 2Eh is to provide external programs with a method for accessing the command parsing and dispatching routines within COMMAND.COM. It searches which copy of COMMAND.COM is the primary shell if more than one copy exists in the system. The copy to which the INT 2Eh vector points is defined as primary.

Last use of this capability permits programs to use COMMAND.COM's internal command like SET to modify environment variables. Since it accesses both the interpreter and dispatcher routines of COMMAND.COM, INT 2Eh can even be used to launch a batch file. However, its use is highly restricted by the fact that COMMAND.COM is not re-entrant. Any program that uses it to launch a batch file will take a batch file that directly launches another never return to its invoking

[illegible] COMMAND.COM supports this interrupt, it's only prudent to verify that the interrupt service routine exists before attempting to use it.

The assembly language program HAVE2E.ASM shown in Figure 10-12 provides a C-callable routine that returns TRUE if the first byte of the service routine for INT 2Eh is not the IRET opcode that DOS points the vector to by default. The routine returns FALSE if the byte is equal to the IRET opcode.

Figure 10-12. HAVE2E.ASM

```
        model small,c
        code
have2e  proc                    ; returns 1 if ISR exists, else 0
        public  have2e
; int have2e( void ); /* prototype */
        mov     ax,352Eh
        int     21h
        mov     ax,es           ; test for empty just to be safe
        or      ax,bx           ; although MS-DOS never leaves this
        jz      hl              ; vector all zeroes
        mov     al,es:[bx]
        xor     al,0CFh         ; opcode for IRET
        jz      h1
        mov     ax,1
hl:     cbw
        ret
have2e  endp
        end
```

Its Use [illegible] INT 2Eh to take a command string such as DIR *.* or anything else a user might normally type at the prompt, put a CR at the end of it and a byte count at the front, just as INT 21h, AH=0Ah does, point DS:SI to the count byte, then invoke INT 2Eh. The command is executed. But to use INT 2Eh successfully, your code must follow several rather strict guidelines. This capability has never been [illegible] documented. Microsoft's *MS-DOS 6 Programmer's Reference* describes INT 2Eh merely as "[illegible] for use by COMMAND.COM only," despite the fact that it's never called within COMMAND.COM. As a result, INT 2Eh lacks most of the error-trapping abilities of more normal functions.

[illegible] The most important restriction on the use of this interrupt is that no registers, not even the stack segment and stack pointer, are preserved. Immediately at entry to the service routine, the return address to the terminate-and-stay-resident portion of COMMAND.COM is popped off of dedicated storage areas in COMMAND.COM's own data segment. (To complicate matters, the disk-based version of COMMAND.COM uses [illegible] INT 2Eh internally to load overlays, so it saves and restores the caller's stack.)

[illegible] Most applications can't meet the most obvious setup when you call INT 2Eh: you must save a [illegible] long enough to store the CS:IP address you return to when your CS and IP are valid. Not so obvious is the fact that INT 2Eh is not reentrant. That is, if it is called a second time [illegible] before the first call is finished, the second call destroys the return address for the first invocation, leading to system lockup.

It's possible to overcome [illegible] lack of reentrancy. The trick is to copy all critical data areas from the COMMAND.COM data segment to dedicated memory space obtained specifically for the purpose, then invoke INT 2Eh and upon return restore the data areas from the saved copy. This is essentially how the [illegible] command in 4DOS works, so it can operate successfully from within a batch file.

The program DO2E.ASM [illegible] Figure 10-13 contains the function do2e(), which sets everything up properly before invoking the interrupt, executing a command string, and regaining control upon return.

Figure 10-13. DO2E.ASM

```
.model small,c
 code
do2e    proc    uses ds si di, cmdstr:ptr byte
        public  do2e
; void do2e( char * cmdstr ); /* prototype */
        push    ds                  ; save data segment regardless of model
        mov     si,cmdstr           ; small model
;       lds     si,cmdstr           ; large model
        mov     cs:svss,ss          ; save stack pointer
        mov     cs:svsp,sp
        cld
        int     2Eh                 ; issue command
        cli
        mov     ss,cs:svss          ; restore stack pointer
        mov     sp,cs:svsp
        pop     ds                  ; restore data segment
        sti
        cld
        ret
        even                        ; for best 286+ usage
svss    dw      0
svsp    dw      0

do2e    endp
        end
```

This routine should not be used unless have2e() returns TRUE to indicate that the interrupt is in fact present in your system. The command string passed to the do2e() function must be in a special format, the same format in which COMMAND.COM's input buffer is set after key scan input. The first byte of the string must contain a binary count of the string's length (excluding the count byte and the terminating carriage return character), and the string must be terminated by an 0Dh (CR) character.

Although you can build your own routines using only the do2e() function (INT 21 ORIGIN's easier if you work through an intermediate level support routine such as the C function shown in Figure 10-14.

Figure 10-14. SEND2E.C

```
/*************************************************************
 *   Send2E.C - support for INT 2Eh                          *
 *   Jim Kyle, July 1990                                     *
 *************************************************************/
#include <stdio.h>
#include <string.h>

int have2e( void );                 /* prototype */
void do2e( char * cmdstr );         /* prototype */

int Send2E( char * command )
{ char temp[130];
  int retval;

  if( retval = have2e() )
    { sprintf( temp, "%c%s\r", strlen( command ), command );
      do2e( temp );
    }
  return retval;
}
```

This snippet of code takes just the command line itself as you would type it at the prompt, and adds the character count and terminating CR. It then passes the edited string on to INT 2Fh using the assembly language routine. These actions happen only if the interrupt is present, if not, they are skipped. Finally, Send2E returns TRUE if the command was passed to INT2F and FALSE if it was not.

The program in Figure 10-15 runs Send2E in a loop, making a little command interpreter.

Figure 10-15. TEST2E.C

```
/*
TEST2E.C
        Revised August 1992 - jk
Turbo C++ 2.0:
    tcc test2e.c send2e.c do2e.asm have2e.asm
Microsoft C 6+:
    cl -qc test2e.c send2e.c -MAmx do2e.asm have2e.asm
Borland C++ 3+:
    bcc test2e.c send2e.c do2e.asm have2e.asm
*/

#include <stdlib.h>
#include <stdio.h>
#include <string.h>

main()
{
  char buf[128];
  for (;;)
    { fputs("$  ", stdout);
      gets(buf);
      if ((strcmp(buf, "bye")    0 || strcmp(buf, "BYE") == 0) ||
          (strcmp(buf,  exit ) == 0 || strcmp(buf, "EXIT") == 0))
        break;
      Send2E(buf);
    }
    puts("Bye");
}
```

We already saw this program in Chapter 9 on TSRs where it was used with Ray Michels' TSR skeleton to create a command-driven command interpreter TSR2I.

It's worth noting that this program and INT 2Fh in general is compatible with the installable command interface discussed earlier in this chapter. For example, if you ran our INSTCMD program, you could issue its command to command.com: C:\>INSTCMD using an INT 2Fh program such as TEST2E or TSR2I.

INT 2Fh creates an identical environment with corresponding exit to the command loop of COMMAND.COM. Each command issued to the COMMAND child program terminates. So, this would be expected to work. But, as we saw earlier, subject to the re-entrancy question, INT 2Fh supports a number of services to obtain from the command processor.

An interesting thing happens when a program uses Send2E to issue a SET command. The master environment, instead of an exact copy of the environment belonging to the program, is updated. Using INT 2Fh in this way is a quick and dirty way of changing the master environment; other, safer, techniques were detailed earlier in this chapter in this section. "Using the Environment."

Notice that the issue of error checking is not addressed in Send2E. That's because the issue is much more complex than just saving the data area and restoring them. Although that's necessary, other considerations must also be addressed to make INT 2Fh calls robust enough for dependable use.

The first question that arises is how much of the DOS area Greenberg's article in *Programmer's Journal* referenced at the start of this section suggested that 120 bytes would include all necessary information for DOS versions 2.0 through 4.01. However, not all of that 120 bytes

needed to be restored and the locations that required restoration varied from one DOS version to the next. DOS 5.0 and 6.0 had not yet appeared when Greenberg's article was published, but the 128-byte figure cautioned as a starting point for experimentation.

Another question equally important concerns the methods required to handle CTRL-BREAK interruptions or critical error conditions. In both cases, the normal COMMAND.COM response is inadequate to provide full safety.

Since the last edition of this book was published, the issue of executing INT 21h services like EXEC2.EXE from within a batch file has garnered some publicity. Even before that, Michael Mefford ("Running Programs Pseudo-Simultaneously," *PC Magazine*, February 16, 1988) had written that programs using INT 21h "will not execute batch files or work from within a batch file."

Jeff Prosise, in a good article on undocumented DOS ("Undocumented DOS Undocumented," *PC Magazine*, February 12, 1991), states: "Be careful about how you call interrupt 21h. If you are not, you can crash your system in certain command situations. The reason is that the program you're using is running under a batch file. Since INT 21h is not reentrant, DOS does not expect to run batch files. So if you run a batch file that uses INT 21h from your program, your system will crash."

We too have had problems running programs that use INT 21h from within a batch file, but nothing so dramatic as crashing the system. Instead, we have found simply that EXEC is not handled properly, and that is all we can discuss. At best, we found no indication at all in actual disassembly of COMMAND.COM in the DOS 5.0 that DOS executes batch files. INT 21h is not invoked at all with a COMMAND.COM. Its entry point, however, jumps to the self-same internal code used for batch file processing.

It would be nice if we could develop this issue of INT 21h and batch files once and for all and say what does and does not work and why. However, doing so would take far more effort than the book warrants. Since it appears likely that still another version of DOS will be appearing annually, any research specific to DOS 5.0 or 6.0 or any future version specific would probably fail to apply to the next version.

Greenberg presented a major program written in assembly language to access parts his article and a set of utilities recommended for use when you want to use INT 21h as a tool for serious programming. However, serious interactions with DOS often hinge on such questions as this, and we have not assigned as much as a line of code in the past to safety concerns. Instead, we have relied on the use of INT 21h commands from within our programs to gain access to the many undocumented internal workings of COMMAND.COM. If you need to execute external commands from within your program, use functions such as system or the spawn family of C

Alternatives to COMMAND.COM

Several alternatives to COMMAND.COM now exist, and this section looks at a sampling of them. Some provide complete replacement of the command interpreter, while others retain the existing command interpreter but hide its command-line interface from the user.

4DOS.COM

This command interpreter from J. P. Software totally replaces COMMAND.COM. Originally distributed only as shareware, it is now also available through retail outlets. As this was being written, 4DOS.COM was at version 4.02.

Another alternative is NDOS, distributed by Symantec with recent versions of the Norton Utilities. This is a very slightly scrubbed version of 4DOS version 3.03, which has been customized for interaction with the NU cache enhancer capabilities, but which does not have all of the features added to 4DOS in its version 4. The NDOS supplied with NU 6.0 is a newer version, but is DOS 6.0 compatible. Most of the description of 4DOS that follows applies to NDOS also.

Other products that replace COMMAND.COM include Command Plus, PolyShell and DesqView. I have chosen to cover 4DOS because it typifies the group and because I use it daily and am most familiar with it. Many of the comments apply to all of the programs, but all of the programs offer improved capabilities when compared to COMMAND.COM.

A Total Replacement, Plus More Like all of its competitors, 4DOS provides near total compatibility with COMMAND.COM, even going so far as to duplicate strange actions that most users consider bugs in order to maximize the number of applications that can run without change.

Where COMMAND.COM has only 39 internal commands at most, however, 4DOS now provides more than 80, thereby making many utilities used with COMMAND.COM obsolete. For example, the command processor includes a built-in text editor, ENE, which allows you to edit either the master or the active environment.

For building batch files, 4DOS internal commands are able to draw boxes on the screen or obtain input from the keyboard, even modifying batch file execution decisions. It is even possible to perform arithmetic using the EVAL function and to plug the result into a command to be processed.

One of the most significant features is the ability to do batch file processing entirely in RAM. COMMAND.COM must reload a batch file from disk for each line of input, making it necessary to keep the file available throughout its processing. Reading the file into RAM makes it possible to remove floppy disks, boot from the system phase, and yet continue its execution.

The swapping and improved memory management for which 4DOS has greatly improved on the standard command interpreter. Rather than reload from the same copy that was used to load the program initially, 4DOS automatically swaps out the transient part of RAM, including any data storage that is not necessary for swapping back in. This makes it possible for the program to shrink itself to only 256 bytes in order to free DOS RAM when run on an 80286 or higher system that has the ability to load the resident portion in upper memory.

Version 3.0 of 4DOS and its predecessor, NDOS, used command line switches supplied on the SHELL line in CONFIG.SYS to control how swapping was done. In version 4.0 of 4DOS, the command line switches are replaced by a 4DOS.INI file.

In some versions, it is possible to force the choice of swapping to Extended Memory (XMS), to Expanded Memory (EMS), or to disk, or to not swapping at all. You can also specify the size of your environment area and of the buffer in which command line histories will be saved. Many additional features are controlled by the INI file. Version 4.0 adds such as automatically identifying DIR entry types by the color in which the entries are displayed.

Not to be outdone, the other products have also added featured, hypertext like THELP system. One of the most useful is the ability to edit any of the internal commands from the command line. With all the added power, this feature is needed often.

No Undocumented Features One of the most surprising things about 4DOS is that it is implemented entirely without undocumented calls to DOS and works across all versions of DOS from 2.0 through 6.0. 4DOS does not use undocumented features and knows on which COMMAND.COM depends. Some versions, however, do implement several of them and documents them accordingly. For example, 4.0 DOS 6.0 expected that a few undocumented parts of DOS be used, but they remain at a minimum.

For instance, 4DOS would crash if use of INT 2Fh as a back door into the command interpreter. In version 3.01, INT 2Fh was vectored only to an IRET command. It is, however, part of the 4DOS code segment as well. Hence, the interrupt vector can be used to locate the primary shell, just as with the standard command interpreter.

Since Novell's menu program used with NETWARE required INT 2Fh to operate properly, compatibility suffered. By version 3.0x, 4DOS included an extra TSR program, SETUP2F, which dupli

cated the functions and made the Novell menu usable. But in version 4.0 SHELL.2I went away. It had been fully integrated into 4DOS itself. An INI file setting was added to control how the shell dealt with Novell's dependencies on undocumented aspects of COMMAND.COM. 4DOS being derived from version 3.03 still requires SHELL.2I to function with the Novell menu, although this may have changed with the NLS 7 version.

Here's the official description of SHELL.2I, taken from the on-disk documentation that accompanied the 4DOS version 3.03 release. (Thanks to Tom Rawson and Rex Conn, the creators of 4DOS, for letting me use this excerpt.)

> SHELL.2I accomplishes most of the purpose of INT 2F. It traps calls programs make to Interrupt 21 and loads a secondary shell to execute them. With one exception, this should make programs that use INT 21 work properly.
>
> The exception is programs that use INT 21 to issue SET commands intended to modify the master environment. Under COMMAND.COM, the INT 21 is executed in the primary command processor, and therefore correctly modifies the master environment when a SET command is executed. Since SHELL.2I uses a secondary command processor to execute the commands, a SET command will modify the secondary command processor's environment, and not the master environment. As of this writing, the only program we're aware of that uses INT 21 to execute SET commands is Personal REXX from Mansfield Software.
>
> SHELL.2I starts the command processor to run a secondary shell. The name of the command processor is obtained from the COMSPEC environment variable that was in effect at the time SHELL.2I was loaded. NOTE: the COMSPEC environment variable setting in effect when SHELL.2I is invoked by an INT 2F from another program. In general this doesn't matter, but remember that if you change COMSPEC during the operation of your system, those changes won't be noticed by SHELL.2I when it loads the secondary shell. Your command parameters for a 4DOS shell created by SHELL.2I come from the 4DOSHELL environment variable. This is checked for any secondary 4DOS shell.

Sample Program: An Environment Editor

It's time to put everything together into a useful sample program that illustrates this chapter's topics and that also potentially is useful. The program ENVEDIT.C lets you edit either the master environment or the active environment. It's slower than a shell utility that's written to connect to ENVEDIT can be used with any command interpreter that executes INT 21h in its own code space and that follows COMMAND.COM's conventions that is, DOS and OS/2 protect the same segment address. Except for INT 2Fh, no setup for ENVEDIT is necessary. Compatible versions available.

In our first edition, ENVEDIT operated only on the master environment. This restriction made it unusable in such common situations as running a DOS session under Windows. So the current version adds a capability to edit the current active environment. You should note, however, that ENVEDIT can't edit the environment within one DOS session under Windows and have your changes take effect in any other session. Because each session has its own private current active copy, and you would have to access the copy that Windows keeps to create these individual ones.

ENVEDIT first locates the desired environment block and then locates the specific variable to be edited. It's called with the variable name as its argument. Typing it without any arguments displays a brief summary of how it is to be used, followed by a list of all the variables and their current contents in the specified environment. You select which environment to edit by means of the /option switches: /M for master or /A for active. In the absence of any /option switch, the master environment is edited if running from DOS. If running under Windows, the active environment is automatically used.

Most of the specific techniques that ENVEDT uses have already been explained earlier in this chapter. The value of this program is that it shows you how to put the pieces together. In addition to ENVEDT.EXE, the program requires the support routines in ENVPKG.ASM and NXTEVAR.ASM, plus a new module, EEA.ASM. Environment Editor assembly code.

ENVEDT.EXE (Figure 10-16) has been tested only with Borland C++, but it should work equally well with Microsoft compilers. EEA.ASM has been tested with Turbo Assembler and with MASM Ver. 5.1. The finished program has been tested with both COMMAND.COM and 4DOS.COM as the command shell, and with DOS versions ranging from 3.2 to 6.0.

Figure 10-16 ENVEDT.C

```
/*************************************************************
 *  ENVEDT.C - Editor for Master Environment Variables       *
 *  Jim Kyle, July 8, 1990                                   *
 *  major revision August 22, 1992 - jk                      *
 *                                                           *
 *  qcl envedt.c eea.obj envpkg.obj nxtevar.obj              *
 *   or  cl envedt.c -MAmx eea.asm envpkg.asm nxtevar.asm    *
 *   or bcc envedt.c eea.asm envpkg.asm nxtevar.asm          *
 *                                                           *
 *************************************************************/
#include <stdio.h>
#include <stdlib.h>
#include <conio.h>
#include <string.h>

#include "undocdos.h"                   /* defines structures */

#ifndef FP_SEG
#define FP_SEG(f) (*((unsigned *)&(f) + 1))
#endif

#ifndef FP_OFF
#define FP_OFF(f) (*((unsigned *)&(f)))
#endif

extern char far * nxtevar( char far * wptr );
extern char far * mstenvp( void );
extern void max_xy( int *x, int *y );
extern int IsWin3( void );
extern int col( void );
extern int row( void );
extern void setrc( int r, int c );
extern int envsiz( char far * envptr);

char far * menvp;                       /* perm ptr to environment */
char far * menv,                        /* pointer to current var */
char far * rest;                          /* pointer to next var */
char far * lstbyt;                      /* adr of last byte used */
char vname[512], *txtptr,               /* working buffer and ptr */
int  nmlen,  insmode = 0,               /* name len, insert flag */
     max_x,  max_y,                             /* screen limits */
     i,      c,                               /* scratchpads */
     begrow, begcol,                    /* cursor, start of text */
     currow, curcol,                          /*     current loc */
     endrow,                                  /*     end of text */
     editing,                           /* loop control flag */
     i_cur, i_max,                      /* cur, max i in txtptr */
     free_env;                          /* bytes free in env */

void findvar( char * varnam )           /* find var, set txtptr */
{ nmlen = strlen( varnam );
  txtptr = NULL;                        /* present not-found flag */
```

```
  while ( *menv )
    { rest = nxtevar( menv ),          /* "rest" always next one */
      sprintf( vname, "%Fs", menv ),
      if( vname[nmlen] == '=')          /* possible match found */
        { vname[nmlen] = '\0';
          if (stricmp( vname, varnam ) == 0)
            { txtptr = &vname[nmlen+1];
              vname[nmlen] = '=';
              return;                  /* found it, get out now */
            }
        }
      menv = rest;                     /* try again with next */
    }
}

void calccrsr( void )                  /* calc currow, curcol */
{ begrow = endrow - (i_max / max_x );
  if (( i_max % max_x ) == 0 )
    begrow++,
  begcol = 0;
  currow = begrow + (i_cur / max_x ),
  curcol = begcol + (i_cur % max_x );
}

void show_var( void )                  /* display var content */
{ setrc( begrow, begcol );                    /* set to start */
  printf( txtptr );                    /* show the string */
  endrow = row();                     /* update end row if scrl */
  if( ! col() &&                      /* adjust for line scroll */
      endrow == (max_y-1) )
    endrow--;
  calccrsr();                          /* establish cursor posn */
}

void do_del( void )
{ for (i=i_cur; txtptr[i]; i++ )       /* slide over one to left */
    txtptr[i] = txtptr[i+1],
  if ( i_max && i_cur >= --i_max )              /* decr length */
    i_cur = (i_max - 1),               /* and adjust if needed */
  free_env++,                         /* account for freed byte */
  setrc( begrow, begcol ),             /* re-display the string */
  printf( txtptr ),
  endrow = row();                         /* hold ending point */
  if( ! col() )                       /* adjust for line wrap */
    endrow--,                            /*   if now in col 0 */
  putchar( ' ' );                      /* erase garbage char */
  calccrsr(),                          /* establish cursor posn */
}

void docher( void )
{ if ( free_env < 3 )                  /* just beep if no space */
    { putchar( 7 );
      return,
    }
  if ( insmode )                      /* open up a hole for new */
    { if ( --free_env < 3 )            /* decr freespace count */
        { putchar( 7 );                 /* and if too little is */
          return,                       /* left, beep and quit */
        }
      for (i = ++i_max; i > i_cur; i--)
        txtptr[i] = txtptr[i-1],
    }
  txtptr[i_cur++] = (char) c,                    /* put char down */
  if ( i_cur >= i_max )               /* check for extending it */
    { txtptr[ ++i_max ] = '\0';                  /* set new EOS */
```

```
      if ( --free_env < 3 )              /* decr freespace count */
        { putchar( 7 );                      /* if too little is */
          return;                          /* left, beep and quit */
        }
    }
  show_var(),                            /* re-display the string */
}

int edtxt( void )                         /* read kbd, do editing */
{ int retval;
  begrow = row(),
  begcol = 0,
  i_max = strlen( txtptr );              /* set buffer index limit */
  i_cur = 0,                              /* and current index val */
  show_var();                               /* display the string */
  for ( editing=1, editing, )            /* main editing loop here */
    { setrc( 0, 70 );                        /* status message loc */
      printf( MODE: %s ", insmode ? "INS" : "REP" );
      setrc( currow, curcol );           /* keep cursor posn curr */
      switch( c = getch() )
        { case 0:                        /* function key or keypad */
            switch( getch() )
              { case 30:                          /* Alt-A, redisplay */
                  show_var(),             /* re-display the string */
                  break,
                case 32                  /* Alt-B, delete variable */
                  printf("\nDELETE this variable (Y/N)? ");
                  if(( getch() & 89 ) == 89 )          /* 89 = 'Y' */
                    { vname[0] = '\0';
                      retval = 1;
                      editing = 0;
                    }
                  break,
                case 71                   /* home, goto first char */
                  i_cur = 0,
                  calccrsr();             /* establish cursor posn */
                  break,
                case 72                                  /* up arrow */
                  if ( (i_cur - max_x ) > 0 )
                    i_cur -= max_x,
                  calccrsr();             /* establish cursor posn */
                  break,
                case 75                                /* left arrow */
                  if ( i_cur > 0 )
                    i_cur--,
                  calccrsr(),             /* establish cursor posn */
                  break;
                case 77:                              /* right arrow */
                  if ( i_cur < i_max )
                    i_cur++,
                  calccrsr(),             /* establish cursor posn */
                  break,
                case 79                     /* end, goto last char */
                  i_cur = i_max,
                  calccrsr(),             /* establish cursor posn */
                  break,
                case 80                                /* down arrow */
                  if ( (i_cur + max_x ) < i_max )
                    i_cur += max_x,
                  calccrsr(),             /* establish cursor posn */
                  break,
                case 82                     /* insert, toggle flag */
                  insmode = !insmode,
                  break,
                case 83:                  /* delete, remove 1 char */
```

```
                do_del(),
                break;
            }                           /* end of special codes */
          break,
        case 8:                         /* backspace del to left */
          if (i_cur)
            { i_cur--,                      /* back up one first */
              do_del();                     /* then do the delete */
            }
          break,
        case 13:                        /* Enter accepts changes */
          retval = 1;
          editing = 0;
          break,
        case 27:                        /* ESC quits without save */
          retval = 0,
          editing = 0,
          break,
        default
          if (c >= ' ' && c < 127)
            docharO,                        /* handle INS or REP */
          else
            putchar( 7 );               /* beep on any other char */
      }
    }
  setrc( endrow, 0 );
  return (retval),
}

void putenvbak( void )                  /* copies back to env */
{ char * locptr;
  int save_size,

  save_size = FP_OFF( lstbyt ) - FP_OFF( rest ) + 1;
  locptr = (char *)malloc( save_size );

  for( i=0, i<save_size, i++ )          /* save trailing data */
    locptr[i] = rest[i],
  for( i=0, vname[i], i++ )             /* copy edited string */
    *menv++ = vname[i],
  if( vname[0] )                        /* if not deleting .  */
    *menv++ = '\0',                     /*    add EOS byte to var */
  for( i=0; i<save_size, i++)           /* copy in trailing data */
    *menv++ = locptr[i],
  free( locptr );                       /* release save area */

  printf("\nENVIRONMENT UPDATED." );
}

void doedit( char * varnam )            /* find var, edit, save */
{ printf("Editing '%s'\n", varnam );
  menv = menvp,                         /* set starting point */
  free_env = envsiz(menv) << 4;         /* get the size in bytes */
  findvar( varnam );                    /* look for the variable */
  for( lstbyt=menv, *lstbyt, )          /* menv set by findvar() */
    lstbyt=nxtevar(lstbyt),             /* locate end of var area */
  if( lstbyt[1] == 1 && lstbyt[2] == 0 )
    { lstbyt += 3;                      /* skip loadfile name */
      while (*lstbyt)
        lstbyt++,
    }
  lstbyt++,
  free_env -= FP_OFF( lstbyt );         /* what's left is free */
  if ( txtptr == NULL )                 /* didn't find the name */
    { free_env -= (nmlen+1);            /* take out free space */
      if ( free_env < 5 )
        { puts("Not found, no room to add.");
          return,
```

```
        }
      printf( "Not found; add it (Y/N)? " );
      if(( getch() & 89 ) != 89 )                    /* 89 = 'Y' */
        return,
      for ( i=0; i<nmlen; i++ )              /* force to uppercase */
        vname[i] = (char) toupper( varnam[i] );
      vname[nmlen] = '=';                    /* add the equals sign */
      vname[nmlen+1] = '\0',                  /* make content empty */
      txtptr   &vname[nmlen+1],           /* set text pointer to it */
      putchar( '\n' );                       /* start on fresh line */
      insmode = 1;                              /* and in INS mode */
    }
  printf( "Free environment space = %d bytes \n", free_env ),
  if ( edtst() )                               /* do the editing now */
    putenvbak();                               /* copy to master env */
  else
    printf("\nENVIRONMENT NOT CHANGED " );
  putchar( '\n' ),
}

void showvars( void )                        /* prints usage message */
{ puts(" USAGE  ENVEDT [env] varname [[name2] ... ]");
  puts( where varname is the name of an env variable");
  puts("   and name2, etc , are optional added names "),
  puts( optional  switch [env] is /M to use Master copy"),
  puts("   or /A to use Active copy of environment."),
  puts("  nCurrent variable names are   );
  menv   menvp,
  for( i 0, i<8, i++ )
    vname[i]    ' ',
  while ( *menv )                              /* get and print names */
    { sprintf(vname+8,   %s , menv ),
      for( i 8, vname[i] != '=', i++ )
        /* all done by for() */ ,
      vname[i] = '\0',
      puts( vname ),
      menv = nxtevar( menv );
    }
  puts("Re-run with name(s) of variable(s) to be edited."),
}

char far * actenvp( void )                   /* trace back to active */
{ WORD parent, self,
        self = _psp;                          /* start with current */
        parent = PARENT( self );                 /* prog's parent, */
        do { self = parent;                /* and go until shell hit */
           } while (( parent = PARENT( self ) ) != self );
        return  (char far *)MK_FP( ENV_FR_PSP( parent ), 0 );
}

void main ( int argc, char **argv )
{ int i, j;
  menvp = IsWin3() ? actenvp() : mstenvp(),      /* set default */
  for( i=1, i < argc; i++ )                    /* first check for args */
    { switch( *argv[i] )
        {
        case '-';                          /* process option switches */
        case '/':
          switch( *(argv[i]+1) )
            {
            case 'M'-                     /* use 2E to get master env */
            case 'm',
              menvp = mstenvp(),
              break,

            case 'A':                        /* back up to active env */
            case 'a':
```

```
            menvp = actenvp();
            break;
          default:
            printf( "Unknown option \"%s\" ignored\n", argv[1] );
          }
        for( j = 1; j < argc; j++ )    /* remove from arg list */
          argv[j] = argv[j+1];
        argc--;                        /* and reduce counts to fit */
        j--;
        break;
      }
  }
if (argc < 2)
  showvars();                          /* list all vars to CRT */
else
  { printf( "Changes will modify %s environment at %Fp\n",
            menvp == mstenvp() ? "MASTER" : "ACTIVE", menvp ),
    max_xy( &max_x, &max_y ),          /* set up screen limits */
    while ( --argc )                   /* process all vars named */
      doedit( *++argv ),
  }
}
```

The program's first action is to establish a default environment based on the return from `_osmajor` at the process's top. Option switches found on the command line. When all arguments have been checked, `main` determines what to do next.

If the only thing left on the command line is the program name itself, `argc` = 2, the `showvars` procedure is called. If one or more additional arguments were present, the `doedit` function would be called for each of them in turn, or else all has been processed. In either case, `menvp` points to the environment area that will be listed or edited.

The `showvars` procedure locates the environment using `menvp` and echoes through it using `putenv`, displaying the name of each variable. The SET internal command does almost the same thing, but it can only work on the primary shell. SET always deals with the local copy of the environment, rather than with the master. `_osmajor` is used to choose between the two methods.

The `doedit` function searches the environment for a variable, again using `_fstrstr` to start each search at the beginning of a variable. `_fstrstr` locates the variable free env to the `_psp` segment bytes of the current memory block using `_memsize`, so that the amount of free space can be calculated later. The `_fstrstr` call is made after `_fstrchr` finds the actual search.

The `findvar` procedure sets pointer `_fstrptr` either to the address of the variable's contents in global work buffer `_fname`, if it is found, or to `NULL`. The `_fstrstr` call tells `doedit` whether the search was successful. Before checking the result, however, `doedit` moves another pointer, `lstvar`, past any remaining variables in the `_fstrstr` buffer. This is a little subspace item we'll see more of. When this is done, the offset portion of `lstvar` is a count of the total number of environment block bytes in use. Subtracting it from the total size of the block leaves in `free_env` as the remainder, the number of bytes still free for use.

With free space prepared, `doedit` then checks the search result. If the name is not found, the procedure asks if you want to add it as a new variable, first verifying that there's room to do so and correcting the `free_env` value to account for the name itself. If you do want to add the new variable, the name is copied into the global work buffer `_fname`, the equal sign `=` and a terminating `0` are added, `_fstrptr` is set to the address of the `0` character (the presently empty new contents), and the `_osmode` flag is set to indicate `INSERT` mode operation. Otherwise, `doedit` returns to `main` to process the next variable in the input list.

If the variable was found, or if a new one is to be added, `doedit` reports the number of bytes still free to use and calls `vedit` to do the actual editing. `Vedit` returns a nonzero value on leaving

[illegible] completion of the editing operation, putenvbak is called to copy the work buffer vname back into the environment block, sliding other data around as necessary to make things fit. If the value returned by editvar is zero, indicating an ESC key bailout, the message "ENVIRONMENT NOT CHANGED" is displayed and doedit() returns.

Before we look at editvar(), which contains the bulk of ENVEDIT's complexity, let's see how varbuf searches for the name. The three pointers that address the block—mem, rest, and stbuf—are declared as far pointers, as they are global in scope, so that all procedures in ENVEDIT can use them. The findvar() routine gets a far pointer—actually one of those in the argv[] array—as its argument. Before its first call to findvar(), vmade and the mem pointer is initialized to the value of memp, the permanent pointer to the block to be edited.

Each time findvar() is entered, the pointer ixptr is set to NULL and the global variable vmade is set to the length of findvar()'s argument. Then findvar() goes into a loop that continues until either the end of the variable list is reached—when the byte pointed to by mem is zero—or the argument is found as a variable name.

Within the loop, the pointer rest is first set to the address of the next variable, using nxtvar(). The current variable is then copied from the environment block to the global work buffer vname, by means of the repeated _fstrcpy() calls in the format modifier. Next, the character at position vmade in the vname buffer is checked. If it is an equal sign, then the variable's name is the right length to be a possible match. If not, no match is possible, so no time is wasted trying to compare the strings.

If the character is an equal sign, it is temporarily replaced by a 0, and the _fstrcmpi() function is used to compare the vname and the argument without regard to case. If they match, the equal sign is put back, ixptr is set to the first byte after it, and findvar() returns successfully. If the lengths of the strings fail to match, rest is copied to mem, and the process repeats for the next variable in the master block.

Upon successful return from findvar(), mem still points to the first byte of the variable being edited. The vname buffer contains an exact copy of the entire variable, including its name and the trailing equal sign, and ixptr points to the first byte of its value in vname. These facts are critical to the operation of editvar(), which does the actual editing.

Once the variables are set up to suit, the cursor position and showvar() are called to display the variable on the screen. The main loop of the editvar() control remains within this loop until you press Alt-D, Enter, or Esc. Any of these keys causes control to editing. Enter and Alt-D set the return value to 1, and Esc sets the return value to 0. The cursor is then positioned just past the end of the variable on the screen, and control returns to doedit().

The routine that shows vname's value at position 0 positions the cursor to the saved starting position, displays the appropriate portion of the variable using fputs(), saves the ending cursor position, and calls the function called to recalculate any necessary adjustments to the saved starting points and to establish the current cursor position within the variable.

If a valid keystroke is pressed, the display should not change, since it is confused. The Alt-D option in ENVEDIT is for when you want to delete the variable entirely, rather than just change it. What you have to tell it is that you really mean it. The program zeroes the first byte in vname[] and then calls showvar() to update the display. This will cause all bytes in the master block, but the following variables close up the gap.

The arrow keys move the cursor as would be expected, with the restriction that the cursor cannot move out of the variable. Thus, a right-arrow has no effect if the cursor is on the top line of the variable, left-arrow keys position it over the first character, and so forth. The Home and End keys move the cursor to the first and last characters, respectively, of the variable. The code for all six of these keystrokes simply changes the value of vmade as appropriate, then calls calcvar() to do the heavy work.

Once edvar has completed and returns a nonzero value, putenvbak handles the job of writing the edited variable back into the master block. It does this by first calculating the number of bytes that must be saved, using the values of rest and lstbot that were set up earlier, and then copying that material from the master block to a temporary block of memory obtained using malloc.

The old contents of master is then copied back to the specified environment block, starting at the address indicated by mem. Finally, the saved material is copied back to follow the changed data and the temporary block released by free. The last action of putenvbak is to display or store the line "ENVIRONMENT UPDATED."

The module ENVVM1.com contains IsWin3() and functions that are used when you are interactively editing the environment variables. It's not shown here, but you can find it on the companion disk if you're curious. The functions in ENVVM1 duplicate others found in the Borland and Microsoft libraries, but the library functions differ greatly between the compilers. The addition of these video routines simplifies the rest of the program by providing identical operation regardless of the compiler you choose.

Here's what the operation of our revised ENVEDIT looks like. First, we just tell it to edit variable OLDPATH:

```
D:\UDOS2\CHAP10> envedit oldpath
Changes will modify MASTER environment at 0316:0000
Editing 'oldpath'
Free environment space   270 bytes
D:\WIN31,D:\VB,D:\UTILS,D:\DOS,D:\TAPE,C:\UV,C:\MAX6,C:\ADDSTOR
ENVIRONMENT NOT CHANGED
```

The second line indicates that ENVEDIT looks to edit the master environment. The next line indicates that I pressed Esc rather than Enter to leave the program, and so the environment didn't change. Next, I repeated the command but added the /a option switch to specify the active environment:

```
D:\UDOS2\CHAP10> envedit /a oldpath
Changes will modify ACTIVE environment at 0AC8:0000
Editing 'oldpath'
Free environment space = 262 bytes
D:\WIN31,D:\VB,D:\UTILS,D:\DOS,D:\TAPE,C:\UV,C:\MAX6,C:\ADDSTOR
```

With the content of OLDPATH displayed, I used the DEL key repeatedly to erase D:\ to change to D:\WIN31, then I pressed Enter to change the variable in memory:

```
D:\VB,D:\UTILS,D:\DOS,D:\TAPE,C:\UV,C:\MAX6,C:\ADDSTOR
ENVIRONMENT UPDATED.
```

Repeating the original command sequence shows that no change occurred in the master environment, that's just what should have happened:

```
D:\UDOS2\CHAP10> envedit oldpath
Changes will modify MASTER environment at 0316:0000
Editing 'oldpath'
Free environment space   270 bytes
D:\WIN31,D:\VB,D:\UTILS,D:\DOS,D:\TAPE,C:\UV,C:\MAX6,C:\ADDSTOR
ENVIRONMENT NOT CHANGED
```

Finally, add the /a switch at the end of the last test to show that its position makes no difference. envedit gets a report that confirms the earlier change was saved to the active environment:

```
D:\UDOS2\CHAP10> envedit oldpath /a
Changes will modify ACTIVE environment at 0AC8:0000
Editing 'oldpath':
Free environment space = 271 bytes.
D:\VB;D:\UTILS;D:\DOS;D:\TAPE;C:\UV;C:\MAX6;C:\ADDSTOR
ENVIRONMENT NOT CHANGED
```

If you're actually running in the primary shell so that the active environment and the master environment are the same block, you will find that ENVEDT reports it is working in the master even if you use the /a switch. This is not an error. The program determines whether it is using the master or the active block by comparing the value in memp with the address of the master environment. If these are equal, as they will be if only one block serves both purposes, the program reports that the master will be modified.

One caveat. Some versions of COMMAND.COM copy the path in the COMSPEC variable into their own data area at system boot time, so it's possible that any changes you make to this variable with ENVEDT may have no effect on system operation. This is not true for all versions, though, and never applies to 4DOS.COM, which provides its own version of ENVEDT anyway.

Conclusion

In this chapter we have looked at a wide variety of topics. They include the basic structure of the input environment, how to write and install a new command interpreter, the DOS hooks for installing new internal commands, the structural structure of a DOS command interpreter, INSTALL, the division of COMMAND.COM into initialization, resident, and transient portions, the DOS environment, the command interpreter backdoor, INT 2Eh, alternative interpreters like 4DOS, and methods for editing the environment.

Each of the covered subtopics reflects the nature of command interpreters. They are, after all, interpreters of human input and producers of human-readable output. While the basic principles to support a command shell are simple, there are enough different forms of input (keyboard, batch file, environment variable, or interpreter backdoor), and there are enough different locations of command code (internal, external, and installable) that we could have easily made this chapter even longer.

It is also important to remember that in MS-DOS as in UNIX, the command interpreter or shell is not part of the operating system shell. This is one reason why some of the techniques presented in this chapter do not work on every DOS machine. You can take a good many of the programs in this book, walk up to any of the 50 million or so DOS machines in existence, and run the program. Not necessarily so with the programs in this chapter, though. If a machine is running some interpreter other than COMMAND.COM, such as Novell's Netbios or even little INSTALL.COM, then techniques such as installing new internal commands, modifying the master environment, or invoking INT 2Eh may or may not work.

This is because it's easy to throw away COMMAND.COM and substitute something completely different. Now it's true that users are also free to change parts of MS-DOS as well by hooking INT 2Fh, for example, and it's also true that such techniques are more widespread than the use of alternative interpreters, but if the command interpreter is not part of the operating system, what's supported is anyone's guess. In other words, there are no DOS guarantees here. But then again, there can't be many areas where an operating system as flexible as MS-DOS

APPENDIX

Undocumented DOS Functions and Data Structures

Acknowledgment

The material in this appendix is an excerpt of a comprehensive list of IBM PC interrupt calls maintained by Ralf Brown. The full list of over 1000 pages is included on the disk accompanying this book. Updates are distributed electronically through CompuServe, the Internet, and various wordwide several times per year. Over two hundred people have contributed to the list's massive size; major contributors of information incorporated in this appendix include Kevin Chappell (who has undocumented behavior calls for Novell NetWare, DR DOS 6.0, John Fulmer (DR DOS and DR Multiuser DOS), and Larry LMM386 LXE Marcos Garcia (DR DOS), David Moore (various undocumented calls), Duncan Murdoch (various undocumented fields and data structures), Ralph E. Johnston (European MS-DOS 4.0), Jack Rose (source of DR DOS), Andrew Rossmore (SMARTDRV 4.0), Markus Seuss (DR Multiuser DOS), and other contributors such as European MS-DOS 4.0 Bug Watch (DOS 3.0, 3.3, 4.0, multiuser 5.0), Matthias Yeung (miscellaneous), and Ralf Brown (DOS 2.x, 3.1 source, DOS 3.3 and 4.0 and multiuser 5.0 and 6.0). Additional miscellaneous contributions were made by David Andrews, Tan-ura Banks, John Sparks, and Dan Lanciani.

Sample Entry

The following sample entry illustrates the various conventions used in this appendix by way of a mythical interrupt call. Detailed explanations of various features follows the sample entry.

INT 2Bh Function 01h **DOS 2.7x only**

GET DWIM INTERPRETER PARAMETERS

The DWIM (Do What I Mean) interpreter is a custom module called COMMAND.COM when it encounters an unknown command or syntax error. The DWIM interpreter attempts to determine what the user meant and returns that guess to COMMAND.COM for execution.

Call With

AH	01h
DS:SI	pointer to buffer for parameter table (see below)
CX	size of buffer

Returns

CF set on error

AX	error code
	01h buffer too small (less than two bytes)

CF clear if successful

CX size of returned data
DX *number of times DWIM interpreter invoked since parameters were last set*

Notes: The DWIM interpreter was apparently never released, due to its large memory requirements and slow operation.

If the given buffer size is at least two bytes but less than the size actually used by the parameter table, the first CX bytes will be copied into the buffer but no error will be returned.

Format of parameter table:

Offset	Size	Description
00h	WORD	size in bytes of following data
02h	WORD	maximum number of error corrections per sector to attempt
04h	WORD	order in which to correct errors 00h left to right 01h right to left *02h most severe first*
—DOS 2.70—		
06h	*BYTE*	*unknown*
07	DWORD	pointer to DWIM statistics record (see INT 2B/AH=03h)
—DOS 2.71—		
06h	*WORD*	*unknown*
08h	DWORD	pointer to DWIM statistics record (see INT 2B/AH=03h)

Note: the statistics record may be placed in a user buffer by changing the pointer with INT 21h/AH=52h.

See Also: *INT 21/AH=04h* INT 2Bh/AH=02h,INT 21h/AX=4401h

The upper-left corner of the header indicates the versions of DOS for which the function is valid on this and previous versions 2.*0 and 2.*1 only. Two other variations are also used: DOS 2+ indicates that the call is valid for all known versions of DOS from 2.00 through 6.00 inclusive, and DOS 3.1-3.3 indicates that the call is valid for DOS versions 3.1 through 3.3 inclusive.

Various attempt functions are called internally by DOS and should be implemented by a user program rather than called. To further distinguish these functions, "Called with" is used instead of "Call with".

Unless it explicitly states that the register or register pair contains the address of the indicated item rather than the item itself.

Register descriptions which are underlined indicate that the register only applies for the value indicated by the preceding bit-level register description. For this example, the value in AX is meaningful only if the carry flag is clear, while the value in DX is always meaningful. The carry flag is clear.

Italicized text indicates that the information is not entirely certain and that particular care—even above that usually exercised—should be exercised when attempting to use it.

Notes, See Also, Notes, and Index sections apply either to the function in general or to the description of a data structure. Notes, Bugs, and Index sections apply to a Return: section apply to the function in general, while those sections appearing within the description of a data structure apply only to the data structure they follow.

Many data structures change between various versions of DOS. To save space, the different versions are listed only when necessary. Unless otherwise noted, the fields are assumed to be common to all versions. Fields are listed in the order in which they appear in memory. For example, the first three fields are common to both DOS 2.*0 and 2.*1, but DOS 2.*0 has a byte where DOS 2.*1 has a word, shifting the remaining field.

One or more fields in a data structure may be pointers to additional data structures. Such data structures are often described in other entries of the appendix, in this case under Interrupt 2Bh function 03h.

[illegible] before the call to the INT [illegible] after the [illegible] BAh or INT 2Fh AH=11h AL=00h [illegible] 2Fh AX=1600h [illegible] 2Fh AX=4300h [illegible] INT 2Fh AX=4B01h [illegible] there's a 0h

The final section [illegible] to refer to Interrupt 28h [illegible] call and Interrupt 21h [illegible] command [illegible] because [illegible] to functions not listed in this appendix are [illegible] etized. See the [illegible]

[illegible] may change [illegible] not [illegible] is [illegible]

INT 15h Function 2000h — DOS 3+
PRINT.COM DISABLE CRITICAL REGION FLAG

Specifies that PRINT.COM should not set the user flag to indicate a DOS [illegible]

Call With
- AX 2000h

See Also: INT 15 AX=2001h

INT 15h Function 2001h — DOS 3+
PRINT.COM SET CRITICAL REGION FLAG

Specifies that [illegible] a DOS [illegible]

Call With
- AX 2001h
- ES:BX pointer to byte which is to be incremented while in a DOS call

See Also: INT 15 AX=2000h

INT 15h Function 4900h — Far East MS DOS
GET DOS TYPE

Determine [illegible] MS DOS [illegible]

Call With
- AX 4900h

Return
- CF cleared if successful
  - AH 00h
  - BL type of DOS running
    - 00h DOS V
    - [illegible] DOS [illegible] MS DOS
- CF set on error
  - AH 80h function not supported

Note: [illegible] DOS [illegible] AX DOS [illegible]

See Also: 21 30h

INT 21h Functions 1 0Ch — NetWare
CHARACTER I/O FUNCTIONS

[illegible] NETX [illegible] special [illegible] the DOS character I/O calls (INT 21h [illegible] 0Ah, 0Bh, 0Ch [illegible] DOS [illegible] I/O calls NETX checks [illegible] "FOO [illegible] BAR BAR" where FOO [illegible] 2) [illegible] string and where [illegible] represents [illegible] NetWare [illegible] NETX temporarily substitutes a [illegible] NETWare [illegible] handles the redirection. See chapter 4 for more information.

INT 21h Function 0Eh — NetWare
SELECT DISK

When [illegible] DOS [illegible] LASTDRIVE value in [illegible] NetWare [illegible] NETX [illegible] drive tables drives A [illegible] Z [illegible] Under NetWare the actual number of [illegible] See chapters 2 and 4.

INT 21h Function 13h — DOS 1+
DELETE FILE USING FCB

Although documented, the File Control Block [illegible] and this function has an undocumented quirk.

Call With

AH	13h
DS:DX	pointer to an opened FCB (see below), filename filled with template for deletion ('?' wildcards allowed)

Returns

AL	status
	00h one or more files successfully deleted
	FFh no matching files or all were read only or locked

Notes: [illegible] and sets the [illegible] extended FCB with [illegible] DOS [illegible] may have [illegible] after [illegible] DOS 1.25+ stop the [illegible] DOS 2+ [illegible]

[illegible] system corruption may result when a sub[illegible] MS-DOS [illegible] read only file to be deleted with 21/13. NetWare NETX prevents this.

See Also: 21/41h, 2F/1113h. See 21/52 — system FCBs, chapter 8

Format of File Control Block

Offset	Size	Description
7	BYTE	extended FCB if FFh
6	5 BYTEs	reserved
1	BYTE	file attribute if extended FCB
00h	BYTE	drive number (0=default, 1=A, etc)
01h	8 BYTEs	blank padded file name
09h	3 BYTEs	blank padded file extension
0Ch	WORD	current block number
0Eh	WORD	logical record size

10h	DWORD	file size
14h	WORD	date of last write (see 21/5700h)
16h	WORD	time of last write (see 21/5700h) (DOS 1.1+)
18h	8 BYTEs	reserved (see below)
20h	BYTE	record within current block
21h	DWORD	random access record number (if record size is < 64 bytes, high byte is omitted)

Note: To use an extended FCB, you must specify the address of the FFh flag at offset -7, rather than the address of the drive number field.

Format of reserved field for DOS 1.0:

Offset	Size	Description
16h	WORD	location in directory (if high byte = FFh, low byte is device ID)
18h	WORD	number of first cluster in file
1Ah	WORD	last cluster number accessed (absolute)
1Ch	WORD	current relative cluster number within file (0 = first cluster of file)
1Eh	BYTE	dirty flag (00h=not dirty)
1Fh	BYTE	unused

Format of reserved field for DOS 1.10-1.25:

Offset	Size	Description
18h	BYTE	bit 7: set if logical device bit 6: not dirty bits 5-0: disk number or logical device ID
19h	WORD	starting cluster number on disk
1Bh	WORD	current absolute cluster number on disk
1Dh	WORD	current relative cluster number within file
1Fh	BYTE	unused

Format of reserved field for DOS 2.x:

Offset	Size	Description
18h	BYTE	bit 7: set if logical device *bit 6: set if open* *bits 5-0: unknown*
19h	WORD	starting cluster number on disk
1Bh	*WORD*	*unknown*
1Dh	*BYTE*	*unknown*
1Eh	*BYTE*	*unknown*
1Fh	*BYTE*	*unknown*

Format of reserved field for DOS 3.x:

Offset	Size	Description
18h	BYTE	number of system file table entry for file
19h	BYTE	attributes bits 7,6: 00 SHARE.EXE not loaded, disk file 01 SHARE.EXE not loaded, character device 10 SHARE.EXE loaded, remote file 11 SHARE.EXE loaded, local file bits 5-0: low six bits of device attribute word
---SHARE.EXE loaded, local file (DOS 3.x and 5.0)---		
1Ah	WORD	starting cluster of file on disk
1Ch	WORD	(DOS 3.x) offset within SHARE of sharing record (see 21/52h)

		DOS 5.0 unique sequence number of sharing record
1Eh	BYTE	file attributes
1Fh	*BYTE*	*unknown*

SHARE.EXE loaded, remote file--

1Ah	WORD	number of sector containing directory entry
1Ch	WORD	relative cluster within file of last cluster accessed
1Eh	BYTE	absolute cluster number of last cluster accessed
1Fh	*BYTE*	*unknown*

SHARE.EXE not loaded--

1A	WORD	[illegible] OR specifies
1Bh	WORD	starting cluster of file
1Dh	WORD	number of sector containing directory entry
1Fh	BYTE	number of directory entry within sector

Note: [illegible] address of the device driver header and then the BYTE at 1Ah is overwritten

INT 21h Functions 18h,1Dh,1Eh — DOS 1+
NULL FUNCTIONS FOR CP/M COMPATIBILITY

[illegible] MS-DOS. An equivalent to function 1Fh was reintroduced with DOS 2.0

Call With
AH 18h, 1Dh, or 1Eh
Returns:
AL 00h

Note: Function 18h corresponds to the CP/M BDOS [illegible] get bit map of logged drives" function 1Dh [illegible] 1Eh [illegible]

See Also: 21,20h 21,4459h

INT 21h Function 1Fh — DOS 1+
GET DRIVE PARAMETER BLOCK FOR DEFAULT DRIVE

Return the address of a disk description table for the current

Call With
AH 1Fh
Returns
AL status
00h successful
DS:BX pointer to Drive Parameter Block (DPB; see below for DOS 1.x, 21,32h for DOS 2+)
FFh invalid drive

Note: This call was undocumented prior to the release of DOS 5.0. However, only the DOS 4+ version (i.e. DPB layout) is now documented

See Also: 21,32h

Format of DOS 1.1 and MS-DOS 1.25 drive parameter block:

Offset	Size	Description
00h	BYTE	sequential device ID
01h	BYTE	logical drive number (0=A)
02h	WORD	bytes per sector

04h	BYTE	highest sector number within a cluster
05h	BYTE	shift count to convert cluster to sectors
06h	WORD	starting sector of [illegible] FAT
08h	BYTE	number of copies of FAT
09h	WORD	number of directory entries
0Bh	WORD	number of first data sector
0Dh	WORD	highest cluster number + 1 (number of data clusters + 1)
0Fh	BYTE	sectors per FAT
10h	WORD	starting sector of directory
12h	WORD	address of allocation table

Note: The DOS 1.0 table is the same except that the first and last fields are missing; see 21"32 for the DOS 2+ version.

INT 21h Function 20h — DOS 1+
NULL FUNCTION FOR CP/M COMPATIBILITY

This function corresponds to the CP/M BDOS function "get/set default user (subdirectory) number", which is meaningless under MS-DOS.

Call With
AH 20h

Returns:
AL 00h

See Also: 21/18h, 21"4459h

INT 21h Function 26h — DOS 1+
CREATE NEW PROGRAM SEGMENT PREFIX

Although undocumented, the PSP contains numerous useful fields.

Call With
AH 26h
DX segment of [illegible] to create PSP (see below for format)

Notes: The new PSP is updated [illegible] memory size information. INTs 22h, 23h, and 24h are taken from the current interrupt vector table.
DOS 2+ assumes that [illegible] PSP segment [illegible] PSP except
See Also: 21/4Ch, 21/50h, 21/[illegible], 21/[illegible], 27/62, 2F/[illegible]

Format of PSP:

Offset	Size	Description
00h	2 BYTEs	INT 20h instruction for CP/M-like CP/M-86 program terminate or COM file exit, or first byte of far call for FCB-based PSP
02h	WORD	segment of first byte beyond memory allocated to program
04h	BYTE	unused; filler
05h	5 BYTEs	CP/M-86 far call to MS-DOS dispatcher (FAR JMP to 0000:0) BUG: DOS 2+ PSPs point to 2 nops followed by 0000:0
0Ah	DWORD	CP/M-86 exit address (IP:CS) (INT 22h) for COM files
0Eh	DWORD	address of INT 23h (Ctrl-Break) handler for COM files
12h	DWORD	DOS 1.x: address of INT 24h (critical error) handler for COM files DOS 2+: reserved
16h	WORD	segment of parent PSP
18h	20 BYTEs	DOS 2+: default [illegible] table (one per open file, FFh = closed)
2Ch	WORD	DOS 2+: segment of environment for process

[illegible]	DWORD	DOS 2+ process's SS:SP on entry to last INT 21h call
32h	WORD	DOS 3+ [illegible] (default 20)
[illegible]	DWORD	DOS 3+ [illegible] (default PSP:0018h)
38h	DWORD	DOS 3+ [illegible] PSP (default FFFFFFFFh in 3.x) used by SHARE in DOS 3.3
[illegible]	2 BYTEs	unused by DOS versions <= 6.00
[illegible]	[illegible] BYTEs	Novell [illegible] Novell task id; see Chapter 4
40h	WORD	DOS 5.0 version to return on 21/30h
42h	WORD	MSW [illegible] SP PDB [illegible] linked list; see [illegible]
44h	4 BYTEs	[illegible] DOS [illegible] 6.00
48h	[illegible]	MSW [illegible] Windows application; WINOLDAP [illegible] Windows [illegible] WinOldAp task
49h	7 BYTEs	unused by DOS versions <= 6.00
50h	3 BYTEs	DOS 2+ [illegible] INT 21/RETF instructions
53h	9 BYTEs	unused in DOS versions <= 6.00
5Ch	[illegible] BYTEs	first [illegible] FCB [illegible] first commandline argument; overwrites second FCB if opened
[illegible]	[illegible] BYTEs	[illegible] from second commandline [illegible] commandline [illegible] opened
7Ch	4 BYTEs	[illegible]
80h	128 BYTEs	commandline / default DTA; command tail is BYTE for length of tail, N BYTEs for the tail, followed by a BYTE containing 0Dh

Notes: [illegible] DOS [illegible] may be increased or allo[illegible] first 20 bytes from the default [illegible] however, DOS will only copy the first 20 [illegible] JFT.

[illegible] MS [illegible] use [illegible] at 80h [illegible] in the [illegible] to use [illegible] of 80F[illegible]h.

MS-DOS 5.0 [illegible] program high, the first FCB is empty and the second contains the first parameter.

[illegible] DOS [illegible] PSP [illegible] the "parent" field [illegible] PSP [illegible] 20h [illegible] "or [illegible] the [illegible] PSP [illegible] the preceding paragraph should be a valid MCB whose "owner" is the same as the possible PSP.

Format of environment block

Offset	Size	Description
00h	N BYTEs	first [illegible] ASCIZ string of form "var=value"
	N BYTEs	second environment variable ASCIZ string
	...	
	N BYTEs	[illegible] variable ASCIZ string of form "var=value"
	BYTE	00h

—DOS 3+—

	WORD	[illegible] (normally 1)
	N BYTEs	ASCIZ full pathname of program owning this environment; other strings may follow

INT 21h Function 30h — DOS 2+
GET DOS VERSION

Although documented, the OEM numbers this function returns are not documented

Call With
AH 30h
—DOS 5.0—
AL what to return in BH
00h OEM number as for DOS 2.0-4.0x
01h version flag
Returns:
AL major version number (00h if DOS 1.x)
AH minor version number
BH:CX 24-bit user serial number (most versions do not use this)
—If DOS <5 or AL=00h—
BH OEM number
00h IBM
05h Zenith
16h DEC
23h Olivetti
29h Toshiba
41h Hewlett Packard
99h SPARE II (reserved for OEM DOS NETWORK DOS SMP DOS)
FFh Microsoft, Phoenix
—If DOS 5.0 and AL=01h—
BH version flag
bit 3: DOS is in ROM
other: reserved (0)

Notes: The DOS 2.11 x Compaq bl. Box returns major version 03h, 10 the DOS 2.2 x Compaq bl. it Box returns major version 14 20 x beta versions of the Windows NT DOS box returned major version 3, 30 by NT now supersedes it DOS 5 INT 21, AX=3306h returns DOS 5.50) See Chapter 4

DOS 4.01 and 4.02 identify themselves as version 4.00

Generic MS-DOS 5.50, Compaq MS-DOS 5.31, and others identify themselves as PC-DOS by returning OEM number 00h

The version returned under DOS 4.0x may be modified by entries in the SETVER.EXE program list (see 21/52h)

The version returned under DOS 5+ may be modified by SETVER.EXE; use *21/3306h* to get the true version number

See Also: *21/3306h*, 2F/122Fh

INT 21h Function 32h — DOS 2+
GET DOS DRIVE PARAMETER BLOCK FOR SPECIFIC DRIVE

Determine the address of a disk description table for the specified drive

Call With
AH 32h
DL drive number (00h=default, 01h=A, etc)
Returns:
AL status
00h successful

DS:BX pointer to Drive Parameter Block (DPB) for specified drive
FFh invalid or network drive

Notes: [illegible] DOS 2.x [illegible] supports the DOS 3.3 version of this call with the exception of [illegible] DWORD at offset 2Dh [illegible] updates the DPB after reading the disk; the DPB may be accessed [illegible] DS:SI Vista sets 2Dh to 0 if disk access is not desired. See Chapter 8

[illegible] undocumented for DOS 5.0, but was undocumented in prior versions. Only the DOS 4+ version of the DPB was documented, however.

See Also: 21/1Fh, 21/32h, 21/53h

Format of DOS Drive Parameter Block:

Offset	Size	Description
00h	BYTE	drive number (00h=A, 01h=B, etc)
01h	BYTE	unit number within device driver
02h	WORD	bytes per sector
04h	BYTE	highest sector number within a cluster
05h	BYTE	shift count to convert clusters into sectors
06h	WORD	[illegible] of reserved sectors at beginning of drive
08h	BYTE	[illegible] of FAT
09h	WORD	number of root directory entries
0Bh	WORD	number of first sector containing user data
0Dh	WORD	[illegible] data clusters + 1 16-bit FAT if [illegible] 0FFEDh, else 12-bit FAT
0Fh	BYTE	[illegible] per FAT
10h	WORD	[illegible] sector
12h	DWORD	address of device driver header
16h	BYTE	media ID byte
17h	BYTE	00h if disk accessed, FFh if not
18h	DWORD	pointer to next DPB
—DOS 2.x—		
1Ch	WORD	[illegible] of current directory, 0000h if root, FFFFh if not known
1Eh	64 BYTEs	ASCIZ [illegible] of current directory for drive
—DOS 3.x—		
1Fh	WORD	[illegible] search for free space when writing
21h	WORD	[illegible] of free [illegible] drive, FFFFh if not known
—DOS 4.0-6.0—		
0Fh	WORD	number of sectors per FAT
11h	WORD	sector number of first directory sector
13h	DWORD	address of device driver header
17h	BYTE	media ID byte
18h	BYTE	00h if disk accessed, FFh if not
19h	DWORD	pointer to next DPB
1Dh	[illegible]	[illegible] search for free space when writing usually the last cluster allocated
21h	WORD	[illegible] on drive, FFFFh if not known

INT 21h Function 3302h — DOS 3+
GET AND SET EXTENDED CONTROL-BREAK CHECKING STATE

Set a new state for the extended Control-Break checking flag and return its old state

Call With
AX 3302h

DI new state (00h for OFF or 01h for ON)

Returns

DL old state of extended BREAK checking

Note: This function does not use any of the DOS internal stacks and may thus be called at any time, even during another INT 21h call. One possible use is modifying Control-Break checks from within an interrupt handler or popup TSR. See Figure 6-5.

INT 21h Function 34h — DOS 2+
GET ADDRESS OF CRITICAL SECTION (InDOS) FLAG

Return the address of a flag which indicates when code within DOS is being executed. All functions unsafe to call DOS functions

Call With

AH 34h

Returns

ES:BX pointer to one-byte InDOS flag

Notes: The value of the InDOS flag is incremented whenever an INT 21h function is begun and decremented whenever one completes. However, the InDOS flag alone is not sufficient for determining when it is safe to enter DOS, as the critical error handling decrements the DOS call count and increments the critical error flag for the duration of the time it is waiting for a response to the DOS call. DOS is safe to enter only if both the InDOS flag and the critical error flag are zero.

During INT 28h, it is safe to call some INT 21h functions (0Dh and above) even though the InDOS flag is nonzero. Under versions of DOS 3 and 4, during INT 28h the InDOS flag is 01h, not 02h.

The location of the InDOS flag can be obtained by calling INT 21/AH=52h, which returns a pointer to the List of Lists. In DOS 2.x, the InDOS flag is the byte immediately preceding the List of Lists. In DOS 3.x and 4.x, and COMPAQ DOS 3.0, where the critical section flag is located 1AAh bytes before the InDOS flag, the critical section flag is the byte immediately preceding the InDOS flag.

For DOS 3.1+, the undocumented Get NDA function 21/5D06h can be used to get the address of the critical error flag.

This function was first made public prior to the release of DOS 3.0.

The equivalent in Pascal is the function shown in Program 6-18.

See Also: 21/5D06h, 21/5D0Bh, INT 28h

INT 21h Function 3700h — DOS 2+
"SWITCHAR" GET SWITCH CHARACTER

Determine the character used by DOS to introduce command-line options. Provided as part of the DOS program extension API, but applications should not normally need to call this function.

Call With

AX 3700h

Returns

AL status

00h success

DL current switch character

FFh unsupported subfunction

Notes: This function is documented in some OEM versions of some releases of DOS, and is supported by the OS/2 compatibility box.

The returned value is always 2Fh for DOS 5+.

See Also: 21/3701h

INT 21h Function 3701h — DOS 2+
"SWITCHAR" SET SWITCH CHARACTER

Set the character used by DOS which is used to introduce command-switches.

Call With
AX 3701h
DL new switch character
Returns
AL status
00h successful
FFh unsupported subfunction
Notes: This function is documented in some OEM versions of several releases of DOS and is supported by the OS/2 compatibility box
This call is ignored by DOS 5+
See Also: AL=37h

INT 21h Functions 3702h and 3703h — DOS 2.x and 3.3+ only
"AVAILDEV" SPECIFY \DEV\ PREFIX USE

Get or set the state of the flag which makes a DEV prefix to character device names mandatory

Call With
AH 37h
AL subfunction
02h get availdev flag
Returns:
DL 00h if DEV must precede character device names
nonzero if DEV is optional
03h set availdev flag
DL 00h DEV is mandatory
nonzero DEV is optional
Returns
AL status
00h successful
FFh unsupported subfunction
Notes: All versions of DOS from 2.00 allow DEV to be prepended to device names with and generates an error if the device exists; DEV is ignored for other parts generate an error if they do not exist
Although DOS 3.3+ accepts these calls, they have no effect and subfunction 02h always returns DL=FFh

INT 21h Function 5Fh — Workgroup Connection
WORKGRP.SYS GET ENTRY POINT

WORKGRP.SYS is a driver for Microsoft's Workgroup Connection, which permits communication with Microsoft Windows for Workgroups 3.1 or LAN Manager networks. This call is one way to determine the address of the API handler

Call With
AH 5Fh
BX file handle for device "NETAPI$"
CX 0008h
DS:DX pointer to "\DEVICE\WORKGRP.SYS" (see AX=4402h WORKGRP.SYS)
Returns:
CF clear if successful
AX number of bytes actually read (0 if at EOF before call)
CF set on error
AX error code (05h,06h) (see AH=59h)

INT 21h Function 3Fh — Driver Names
READ DEVICE

A number of device names are used by various drivers to provide interfaces to the drivers by performing reads or writes rather than IOCTL calls. See the list below for a sampling of special device names and the Ralf Interrupt List on disk for details on several of these devices.

See Also: 21 4402h,2F 9400h

Special Device Names:

03C QMPAQ	
386MAXSS	Quarterdeck 386 to the MAX
CACHEMPQ	
EMMXXXX0	Expanded Memory Manager - not all memory managers provide data on access to this device name
EMMQXXX0	QEMM 386 with disabled EMM
EMMXXX0	disabled EMM
NETSETUP	Workgroup Connection WORKGRP.SYS
QEMM386S	Quarterdeck's QEMM 386
SMARTAAR	SmartDrive 3.x
XMSXXXX0	HIMEM.SYS - not used for an API by HIMEM (but possibly by other extended memory managers)
$IDebugDD	Windows low-level debugger
SMMXXXX0	disabled EMM
MMXXXX0	disabled EMM

INT 21h Function 40h — DOS 2+
ADJUST FILE SIZE

Set the size of the specified file to the current file position as set by DS:DX (21 42h) truncating or expanding the file as necessary. This is a little-known but documented feature of the "write to file" call accessed by specifying a write of zero bytes. This feature is a bug in some versions.

Call With
- AH 40h
- CX 0000h
- BX file handle

Returns
- CF clear if successful
  - AX 0000h
- CF set on error
  - AX error code (see *21 59h*)

BUG: Versions of DOS before 3.3 fail to adjust the file size correctly when it is being truncated if the write is not aligned on a cluster boundary. Before truncating, DOS should check whether enough disk space for the expanded file is available, and should allocate space for the file (if extended by seeking to 0 bytes from the end of the file (21/4202h/CX=0, DX=0).

See Also: 2F 1109h

INT 21h Function 41h — DOS 2+
"UNLINK" - DELETE FILE

When invoked via a 21 xD000 this function has the undocumented behavior of allowing wildcards in the filename and enabling an attribute mask, deleting all files matching the wildcards and attribute mask.

Call With
AH 41h
DS:DX pointer to ASCIIZ file name (wildcards not accepted)
CL attribute mask for deletion (server calls only, see below)
Returns:
CF clear if successful
AX destroyed (DOS 3.3)
AL appears to be drive of deleted file
CF set on error
AX error code (02h,03h,05h) (see 21,59h)

Notes: Under DOS 3.1+, wildcards are allowed if the extended open/create is invoked via 21,5D00h, in which case only those specified files are deleted (see 21,660h) and only files matching the attribute mask in CL are deleted.

DOS does not erase the file's data, it merely becomes inaccessible because the FAT chain for the file is cleared.

Deleting a file which is currently open may lead to data corruption. Unless SHARE is loaded, DOS does not close the handles referencing the deleted file, thus allowing writes to a nonexistant file.

See Also: 21,13h, 21,5D00h, 21,60h, 2F,1113h

INT 21h Function 4302h — Chicago
GET VOLUME INFORMATION

[illegible] DOS for Windows [illegible] 21,4302 will be the INT 21h equivalent of the Win32 GetVolumeInformation API. The function will return information on the ability to store long filenames, as well as the file system name (whether the system preserves lower case filenames, the maximum length of a path component accepted, and whether the system supports Unicode).

See 21,714E, 21,7160, and chapter 8.

INT 21h Function 4302h — DR-DOS 3.41+
GET ACCESS RIGHTS

Determines what operations the current process may perform on a specified file without being required to provide a password.

Call With
AX 4302h
DS:DX pointer to ASCIIZ pathname
Returns
CF clear if successful
CX access rights
bit 0 owner delete requires password
bit 1 owner execution requires password (FlexOS)
bit 2 owner write requires password
bit 3 owner read requires password
bit 4 group delete requires password
bit 5 group execution requires password (FlexOS)
bit 6 group write requires password
bit 7 group read requires password
bit 8 world delete requires password
bit 9 world execution requires password (FlexOS)
bit 10 world write requires password
bit 11 world read requires password

AX equals CX DR DOS 5.0
CF set on error
AX error code

Notes: This protection scheme was been coordinated with Concurrent Digital Research Novell operating systems DR DOS 3.41+ DRMDOS 5.x and FlexOS 2+

Only FlexOS actually uses the "execution" bits DR DOS 3.41+ treats them as "read" bits

This function is documented for DR DOS 6.0 and corresponds to the "Get/Set File Attributes" function subfunction 2 documented in Concurrent DOS

DR DOS 3.41+ 5.x only use bits 0–3 Only DR DOS 6.0 using a DRMDOS 5.x security system allowing for users and groups uses bits 4–11

See Also: 21/4303h

INT 21h Function 4303h — DR-DOS 3.41+
SET ACCESS RIGHTS AND PASSWORD

Specify which operations may be performed on a file without a password, and optionally set the file's password

Call With
AX 4303h
CX access rights
bits 0–11 see 21/4302h
bit 15 new password is to be set
DS:DX pointer to ASCIZ pathname
ES:DI new password if CX bit 15 is set blank padded to 8 characters

Returns
CF clear if successful
CF set on error
AX error code

Notes: If the file is already protected the old password must be added after the pathname separated by a semicolon

This function is documented for DR DOS 6.0 and corresponds to the "Get/Set File Attributes" function, subfunction 3 documented in Concurrent DOS

See Also: 21/4302h 21/4454h

INT 21h Function 4304h — DR-DOS 5.0+
GET ENCRYPTED PASSWORD

Get the encrypted password for a file

Call With
AX 4304h
additional arguments (if any) unknown

Returns:
CF clear if successful
AX unknown
CX unknown (same as AX)
CF set on error
AX error code (see 21/59h)

See Also: 21/4303h, 21/4305h

INT 21h Function 4305h — DR-DOS 5.0+
SET EXTENDED ATTRIBUTES

This function permits the extended attributes, and optionally the encrypted password, for a file to be set.

Call With
- AX 4305h
- *additional arguments if any unknown*

Returns
- CF clear if successful
- CF set on error
  - AX error code (see *21,59h*)

See Also: 21,4304h

INT 21h Function 4400h — DOS 2+
IOCTL - GET DEVICE INFORMATION

A [illegible] Get Device Information word has a number of undocumented attribute bits

Call With
- AX 4400h
- BX handle

Returns
- CF clear if successful
- DX device information word
  - character device
    - 15 [illegible] process IOCTL requests (see *21,4402h,4403h*)
    - 13 output until busy supported
    - 11 [illegible] (see IOCTL calls) (see *21,4406h*)
      - set indicates device
    - 6 EOF [illegible]
    - [illegible]
    - 4 device is special (uses INT 29h)
    - 3 clock device
    - 2 NUL device
    - 1 standard out
    - 0 standard input
  - disk file
    - 15 [illegible] (DOS 3+)
    - [illegible] (DOS 3+)
    - [illegible]
    - 8 DOS 4+ [illegible] (INT 24 [illegible] disk space errors)
    - 7 clear indicates file
    - 6 file has not been written
    - 5-0 drive number (0=A)
- AX destroyed
- CF set on error
  - AX error code (01h,05h,06h) (see *21,59h*)

Note: The value returned corresponds to the [illegible] of device driver's attribute word if the handle refers to a character device

See Also: *21,4401h*, 21,52h, 2F,122Bh

INT 21h Functions 4402h, 4403h — Third Party Drivers
IOCTL INTERFACES

Many third-party [illegible] use 21 4402 and 21 4403 [illegible] IOCTL [illegible] See [illegible] at some [illegible] IOCTL interfaces include:

EMMXXXX0	386 memory managers - Global EMM Import Specification
QEMM386	Quarterdeck QEMM 386
386MAX$S	Qualitas 386MAX
SMARTDRV	SMARTDRV.SYS [illegible] AID or SMARTDRV.EXE
3COMMAND	Network [illegible] Interface Spec NDIS [illegible] Manager
NETWORKS	Windows for Workgroups [illegible] WORKGROUPS
varies	[illegible]

INT 21h Function 4404h — DBLSPACE.BIN
IOCTL - FLUSH OR INVALIDATE INTERNAL CACHES

DBLSPACE.BIN of the DoubleSpace disk compression [illegible] MS-DOS 6.0

Call With
- AX 4404h
- BL drive number (00h = default, 01h = A:, etc)
- CX 000Ah (size of DSPACKET structure)
- DS:DX pointer to DSPACKET structure (see below)

Returns
- CF clear if IOCTL successful (check DSPACKET for actual status)
  - AX number of bytes actually transferred
- CF set on error
  - AX error code (01h, 05h, 06h, 0Dh) (see AH=59h)

See Also: *2F 4A11h BX=0000h*

Format of DSPACKET structure

Offset	Size	Description
00h	WORD	signature 4442h ("DM")
02h	BYTE	command code 46h = flush internal caches 49h = flush and invalidate internal caches
03h	WORD	result code return 4E4Bh ("OK") if successful, else unchanged
05h	5 BYTEs	padding

INT 21h Function 4409h — DOS 3.1+
IOCTL - CHECK IF BLOCK DEVICE REMOTE

Although documented, this call returns more information than is indicated in the official documentation.

Call With:
- AX 4409h
- BL drive number (00h=default, 01h=A:, etc)

Returns
- CF clear if successful
  - DX device attribute word
    - bit 15: drive is SUBSTituted

bit 12 drive is remote
bit 9 direct I/O not allowed
CF set on error
AX error code (01h,0Fh) (see #2750)
Note: Only bits 0-6 of DX (or of local device attributes word from the device driver header (see #2752)) are copied across; the other bits appear to be undefined
See Also: AX 4400h, AX 4402h, AX 122Bh

INT 21h Function 440Dh — DOS 3.2+
IOCTL - GENERIC BLOCK DEVICE REQUEST

Although documented, this call provides undocumented subfunctions to manipulate a disk's serial number and specify whether access to a drive is allowed

Call With
AX 440Dh
BL drive number (00h default, 01h=A, etc)
CH category code
08h disk drive
CL function
46h (DOS 4+) set volume serial number (see also AX 6901)
47h (DOS 4+) set access flag
48h (Omnigo) lock/unlock drive
49h (Omnigo) eject drive
66h (DOS 4+) get volume serial number (see also AX 6901)
67h (DOS 4+) get access flag
DS:DX pointer to parameter block (see below)
Returns
CF set on error
AX error code (see #2750)
CF clear if successful
DS:DX pointer to data block if CL=60h or CL=61h
Notes: DOS 4.01 seems to ignore the high byte of the number of directory entries in the BPB for diskettes
Functions 46h and 66h were undocumented in DOS 4.x, but have been documented for DOS 5.0 and later
See Also: AX 6901h, AX 0802h, AX 122Bh

Format of parameter block for functions 46h, 66h:

Offset	Size	Description
00h	WORD	info level (00h), set before calling
02h	DWORD	disk serial number (binary)
06h	11 BYTEs	volume label or "NO NAME "
11h	8 BYTEs	system type ("FAT12 " or "FAT16 ") if CL=66h on return

Format of parameter block for functions 47h, 67h:

Offset	Size	Description
00h	BYTE	special function field (must be zero)
01h	BYTE	disk access flag: 0=zero, 1=access allowed by driver

INT 21h Functions 4410h 4418h — DR DOS
OBSOLETE DR DOS FUNCTIONS

DR DOS [illegible] of the [illegible] DR DOS [illegible] as MS DOS [illegible] DR DOS [illegible] 4458h [illegible] 4450 4458h [illegible] of Novell DOS [illegible] MS DOS [illegible] See 21/4450 4458, and chapter 4

INT 21h Function 4451h — Concurrent DOS v3.2+
INSTALLATION CHECK

Determine whether Digital Research Concurrent DOS version 3.2 or higher is running

Call With
AX 4451h

Returns
CF set if not Concurrent DOS
AX error code (see *21/59h*)
CF clear if successful
AH single tasking, multitasking nature
10h single tasking
14h multitasking
AL operating system version ID (see below for multitasking, 21/4452h for single tasking)

Notes: Version 4.0 of Concurrent DOS XM 5.0 (possibly earlier) sets the version is also stored in the environment variable VER

Use this function if you are looking for multitasking capabilities, 21/4452h for single tasking this call should never return the single tasking values. It returns an error under DR DOS

See Also: 21/4452h, 21/4459h

Values for version ID
32h Concurrent PC DOS 3.2
41h Concurrent DOS 4.1
50h Concurrent DOS XM 5.0 or Concurrent DOS 386 1.1
60h Concurrent DOS XM 6.0 or Concurrent DOS 386 2.0
62h Concurrent DOS XM 6.2 or Concurrent DOS 386 3.0
66h DR Multiuser DOS 5.1
67h Concurrent DOS 5.x

See Also: 21/4452h, 21/4459h

INT 21h Function 4452h — DR DOS 3.41+
DETERMINE DOS TYPE/GET DR DOS VERSION

Determine whether running under Digital Research DR DOS, Novell DOS, or Caldera OpenDOS, MS DOS [illegible]

Call With
AX 4452h
[illegible]

Returns
CF set if not DR DOS
AX error code (see *21/59h*)
CF clear if DR DOS
AH single tasking, multitasking

10h single tasking
14h multitasking
AL operating system version ID (see below for single tasking,
21 4451h for multitasking)
DX same as AX

Notes: [illegible] DR-DOS [illegible] stored [illegible] available [illegible] V2.R
[illegible] 21 4451h [illegible] looking for multitasking.
[illegible] see IN-DRDOS.ON Chapter 4

See Also: AX=4412h AX=4451h AX=4459h

Values for version ID

00h	DOS 1.x
05h	DR DOS 3.41
06h	DR DOS 3.42
07h	DR DOS 5.00
08h	DR DOS 6.00
0Eh	Enix DOS
11h	DR DOS 6.0 March 1993 update for WIN
20h	Novell DOS 7.0

INT 21h Function 4454h — DR-DOS 3.41+
SET GLOBAL PASSWORD

Specify the master password for accessing files

Call With
AX 4454h
DS:SI [illegible] password [illegible] padded [illegible] 8 characters

See Also: 21 4303h 21 4414h

INT 21h Function 4456h — DR-DOS 5.0+
HISTORY BUFFER CONTROL

Call With
AX 4456h
DL flag
bit 0 set for COMMAND.COM history buffer, clear for application

Returns
[illegible]
200h if DL bit 0 set, 400h if clear DR DOS 6.0

Note [illegible] COMMAND.COM of DR DOS 6.0

INT 21h Function 4457h — DR-DOS 5.0+
SHARE/HILOAD CONTROL

Sys [illegible] SHARE [illegible] or not HILOAD should place the DR DOS kernel into high memory

Call With
AX 4457h
DH subfunction
00h enable disable SHARE
DL new state
00h disable
01h enable
else Returns AX unknown

01h get HILOAD status
Returns AX *status*
0000h off
0001h on
02h set HILOAD status
DL new state (00h off, 01h on)
Returns: AX unknown
other
Returns AX *unknown*

Note: This function is called by COMMAND.COM of DR-DOS 6.0 if with /P specified and is supported by later versions of DR-DOS. Novell DOS

See Also: AX=4457h DX=FFFFh

INT 21h Function 4457h Subfunc FFFFh — DR-DOS 6.0
GET SHARE STATUS

Call With
AX 4457h
DX FFFFh
Returns
AX SHARE status
See Also: 2F 1000h

INT 21h Function 4458h — DR-DOS 5.0+
GET POINTER TO TABLE OF VARIOUS INTERNAL VALUES

Determine the address of an internal table of useful DR-DOS values and pointers

Call With
AX 4458h
Returns:
ES:BX pointer to internal table (see below)
AX *undocumented (0Bh for DR-DOS 5.0, 0Dh for DR-DOS 6.0)*

See Also: 21 4457h

Format of internal table:

Offset	Size	Description
00h	*DWORD*	*pointer to unknown item*
04h	*BYTE*	*unknown*
05h	WORD	K of extended memory at startup
07h	BYTE	number of far jump entry points
08h	WORD	segment of code/data far jumps to DR-DOS entry points (see below)
—DR-DOS 6.0—		
10h	WORD	segment of loaded or HMA resident DMA buffer
		HMA memory block (see below) or 0000h if not enough memory or FFFFh
12h	WORD	pointer to segment of device driver chain (see below)
		CONFIG or 0000h if already used
14h	WORD	segment of kernel loaded to HMA (offset is HMA or first used
		HMA memory block (see below) or 0000h if none, segment or FFFFh

Note: The segment passed to the DR-DOS 6.0 CONFIG environment variables (excluding COMSPEC, VER and DOS) is only valid for programs/drivers called from CONFIG.SYS; after which it is set to zero later and the area lost

Format of jump table for DR-DOS 5.0-6.0:

Offset	Size	Description
00	5 BYTEs	far jump to kernel entry point for CP/M CALL 5
05	5 BYTEs	far jump to kernel entry point for INT 20
0A	5 BYTEs	far jump to kernel entry point for INT 21
0F	5 BYTEs	far jump to kernel entry point for INT 22 (IRET)
14	5 BYTEs	far jump to kernel entry point for INT 23 (IRET)
19	5 BYTEs	far jump to kernel entry point for INT 24
1E	5 BYTEs	far jump to kernel entry point for INT 25
23	5 BYTEs	far jump to kernel entry point for INT 26
28	5 BYTEs	far jump to kernel entry point for INT 27
2D	5 BYTEs	far jump to kernel entry point for INT 28
32	5 BYTEs	far jump to kernel entry point for INT 2A (IRET)
37	5 BYTEs	far jump to kernel entry point for INT 2B (IRET)
3C	5 BYTEs	far jump to kernel entry point for INT 2C (IRET)
41	5 BYTEs	far jump to kernel entry point for INT 2D (IRET)
46	5 BYTEs	far jump to kernel entry point for INT 2E (IRET)
4B	5 BYTEs	far jump to kernel entry point for INT 2F

Notes: All of these entry points are redirected through this jump table to allow the kernel to be relocated into high memory while leaving the actual entry addresses in low memory for maximum compatibility.

Format of HMA Memory Block (DR DOS 6.0 kernel loaded in HMA):

Offset	Size	Description
00	BYTE	signature for DR DOS HIMEM Memory Block ('Z' if last block)
01h	WORD	size of this block in bytes (at least 10h)
03h	8 BYTEs	owner of HIMEM Memory Block (interpreted by HIMEM)
		00h system
		01h KEYB
		02h NLSFUNC
		03h SHARE
		04h TaskMAX
		05h COMMAND
0Bh	?	usable for system code and data (DR DOS INRs such as KEYB hooks interrupts to segment FFFFh instead FFFFh)

INT 21h Function 4459h — DR MultiUser DOS 5.0

CP/M compatible API

This function executes a CP/M API call as provided by Digital Research's MultiUser DOS.

Call With:
- AX = 4459h
- CL = function number (see table of CP/M API calls)
- DS:DX = parameters

Notes: DR DOS 5.0 supports CP/M API calls via INT 224 (00E0h) instead of function 4459h.
This API is also available via INT E0h.

See Also: INT 21 4452h

INT 21h Function 4Ah — DOS 2+
RESIZE MEMORY BLOCK

Although documented, this function has undocumented behavior when there is not enough memory to satisfy the request.

Call With
- AH 4Ah
- BX new size in paragraphs
- ES segment of block to resize

Returns:
- CF clear if successful
- CF set on error
  - AX error code (07h,08h,09h) see *21/59h*
  - BX maximum paragraphs available for specified memory block

Notes: Under DOS 2.11 through 6.00, if there is insufficient memory to expand the block as much as requested, the block will still be resized as large as possible, rather than remaining unchanged.

DOS 2.11–6.00 coalesces any free blocks immediately following the block to be resized.

See Also: *21/48h*, 21/49h

INT 21h Functions 4B01h and 4B04h — DOS 2+
"EXEC" - LOAD AND/OR EXECUTE PROGRAM

In addition to the documented service to execute a child process and load an overlay, the EXEC function also has a formally undocumented subfunction to load and relocate a program without beginning execution. The European OEM version of DOS 4.00 does support this undocumented subfunction to load a child process in the background.

Call With
- AH 4Bh
- AL type of load
  - 00h load and execute (documented)
  - 01h load but do not execute
  - 03h load overlay (documented)
  - 04h load and execute in background (European MS-DOS 4.0 only)
  - 05h set execution state for specified program (see Chapter *DOS Internals*)
- DS:DX pointer to ASCIZ program name (with full path and extension)
- ES:BX pointer to parameter block (see below)

Returns:
- CF clear if successful
  - BX,DX destroyed
  - (AL=04h) AX=process ID of new program's PSP (as with *21/62h*)
- CF set on error
  - AX error code (01h,02h,05h,08h,0Ah,0Bh) see *21/59h*

Notes: DOS 2.x destroys all registers including SS:SP.

Before the process may exit so that there is enough unallocated memory available, it is necessary to release memory with 21/49h or 21/4Ah.

For function 01h, the value is passed to the child program's par on top of the child's stack.

Function 01h has several undocumented features. SS:SP and SS:SP are restored in the EXEC structure on DOS 3+, but were not restored in prior versions.

For a full explanation of function 01h, see Tom Patterson's chapter on the MS-DOS debugger interface in *Undocumented DOS*, 1st Edition.

Some versions, such as DR DOS 6.0, check the parameters and parameter block and return an error if an invalid value, such as an offset of FFFFh, is found.

Programs which load programs under European MS DOS 4.0 must use the New Executable (NE) format.

Newer versions of NE executables begin running with the following register values, where the command tail corresponds to a DOS executable's PSP:0081h and following, except that the trailing carriage return is turned into a NUL (00h):

AX = environment segment
BX = offset of end of load module in environment segment
CX = size of automatic data segment (0000h = 64K)
ES:BP = 0000h
DS = automatic data segment
SS:SP = initial stack

BUGS: DOS 3.30 incorrectly sets DS to point at the current program's PSP.

Under DOS 4.x, bit 14 of 03Bh reads up to 512 bytes (or many if the file contains additional data) from the file. Even for EXE data it overlays up to the next 512 byte boundary.

See Also: *21/4Ch*, 21/64h, 21/80h, INT 2Fh

Format of EXEC parameter block (LOAD) for AL=01h,04h:

Offset	Size	Description
00h	WORD	segment of environment to copy for child process (copy caller's environment if 0000h)
02h	DWORD	pointer to command tail to be copied into child's PSP
06h	DWORD	pointer to first FCB to be copied into child's PSP
0Ah	DWORD	pointer to second FCB to be copied into child's PSP
0Eh	DWORD	(AL=01h) will hold subprogram's initial SS:SP on return
12h	DWORD	(AL=01h) will hold entry point CS:IP on return

Note: Ralf Brown calls this the EPB Structure, but erroneously swaps the last two fields in the DOS 5.0 *MS DOS Programmer's Reference*. This was corrected in the DOS 6.0 reference.

Format of .EXE file header:

Offset	Size	Description
00h	2 BYTEs	EXE signature (either "MZ" or "ZM") 5A4Dh or 4D5Ah
02h	WORD	number of bytes in last 512-byte page of executable
04h	WORD	number of 512-byte pages in executable (includes any partial page)
06h	WORD	number of relocation entries
08h	WORD	header size in paragraphs
0Ah	WORD	minimum number of paragraphs of memory to allocate in addition to executable's size
0Ch	WORD	maximum number of paragraphs to allocate in addition to executable's size
0Eh	WORD	initial SS relative to start of executable
10h	WORD	initial SP
12h	WORD	word checksum (one's complement of sum of all words in executable)
14h	WORD	initial CS:IP relative to start of executable
18h	WORD	offset of first relocation table
		40h or greater for new format (NE, LE, LX, PE, W3, etc.) executable
1Ah	WORD	overlay number (normally 0000h: main program)
—new executable—		
1Ch	*4 BYTEs*	*unknown*
20h	WORD	behavior bits
22h	26 BYTEs	reserved for additional values or info

3Ch	DWORD	offset of new executable or other ext MZ header within disk file, or 00000000h if old style MZ executable
—other—		
10h	var	optional information added by linker, program compressor, etc
N	N DWORDs	relocation items

Notes: If the word at offset 02h is 4, it should be treated as 0B0, since pre-3.10 versions of the MS linker set it that way

If both the minimum and maximum allocation (offset 0Ah/0Ch) are zero, the program is loaded as high in memory as possible. The Windows KERNEL uses this, see Pietrek, *Windows Internals*

The maximum allocation is set to FFFFh by default

The new executable (NE) and Linear executable (LE/LX) headers are described in detail in the on-disk interrupt listing. The NE and Win32 portable executable (PE) formats are both documented by Microsoft

INT 21h Function 4Eh "FINDFIRST" FIND FIRST MATCHING FILE

DOS 2+

Although described in this function, has undocumented fields in its data structure which are used to record the progress of the directory search; an undocumented call, and a useful bug

Call With
- AH 4Eh
- AL special flag if used by APPEND; see note below
- CX file attribute mask: bits 0 and 5 ignored
- DS:DX pointer to ASCIIZ file specification; may include path and wildcards

Returns
- CF clear if successful
  - DTA FindFirst data block (see below)
- CF set on error
  - AX error code (02h,03h,12h) (see *21,59h*)

Notes: Read-only, archive, hidden, and files with the MODE execute-only bit set are found even if hidden, system, and directory attributes are not requested. Under DOS 2.x, searches for attribute 08h (volume label) will also return normal files when under DOS 3.x only the volume label will be returned

This call also returns successfully if given the name of a character device without wildcards. DOS 2.x returns a file of 00h size 0 and the current date and time. DOS 3.x returns attribute 40h and the current date and time

Internally, this call is implemented as FCB call 11h (search for first entry), with the DTA overlaid on the FCB. If AL=80h on entry, the returned found path and will be stored; otherwise, the actual found path will be prepended with the given directory without a path

Under DESQview, this call has been used to obtain exclusive access to shared resources by searching for "SERVER.$$$" in a specified resource directory. The searching of "SERVER.$$$"

BUG: Under DOS 3.x and 4.x, the second and subsequent calls to this function with a character device name and wildcards will return bytes which were left in the internal DOS buffer by an unrelated DOS call which implicitly or explicitly performed a directory search (with or without the volume label set). Such implicit searches are performed by CREATE (*21,5Bh*), OPEN (*21,3Dh*), UNLINK (*21,41h*), and RENAME (*21,56h*)

See Also: *21,11h, 21,4Fh, 21/AX=1BBh, 21/AX=71A1h*

Format of FindFirst data block (in DTA):

Offset	Size	Description
—PCDOS 3.10, PCDOS 4.01, MS-DOS 3.2/3.3/5.0—		
00h	BYTE	drive letter, bits 6-0: remote if bit 7 set
01h	11 BYTEs	search template
0Ch	BYTE	search attributes
—DOS 2.x (and some DOS 3.x)—		
00h	BYTE	search attributes
01h	BYTE	drive letter
02h	11 BYTEs	search template
—DOS 2.x and most 3.x—		
0Dh	WORD	entry count within directory
0Fh	*DWORD*	*pointer to DTA*
13h	WORD	[illegible]
—PCDOS 4.01, MS-DOS 3.2/3.3/5.0—		
0Dh	WORD	entry count within directory
0Fh	WORD	[illegible]
11h	11 BYTEs	[illegible]
all versions, documented fields		
15h	BYTE	attribute of file found
16h	WORD	file time
		bits 11-15: hour
		bits 5-10: minutes
		bits 0-4: seconds/2
18h	WORD	file date
		bits 9-15: year-1980
		bits 5-8: month
		bits 0-4: day
1Ah	DWORD	file size
1Eh	13 BYTEs	ASCIIZ filename+extension

INT 21h Function 50h — DOS 2+

SET CURRENT PROCESS ID (SET PSP ADDRESS)

forces a new value for DOS's record of the current process's PSP segment, thus effectively becoming another process

Call With
AH 50h
BX segment of PSP for new process

Notes: DOS uses [illegible] to associate open files and memory allocation with processes; this call corresponds to process identifiers used by other OSs

[illegible] DOS [illegible] INT 28 handler when first setting the Critical Error flag

[illegible] DOS's [illegible] DOS [illegible] stacks and may thus be called at any time, even during another INT 21h call. See Chapter 6, Figure 6.4.3

Some MS-[illegible] [illegible] although it is thorough one should only call this function [illegible] INT [illegible] prepared to handle invalid addresses. See PSPTEST.C in Chapter 4.

Novell NetWare [illegible] task ID into offsets 32h-33h of the PSP

[illegible] extensions supported by [illegible] DOS 3.x [illegible]

This call was undocumented prior to the release of DOS 5.0
See Also: 2F 26h,21 5Dh,21 63h

INT 21h Function 51h — DOS 2+
GET CURRENT PROCESS ID (GET PSP ADDRESS)

Return the segment address of the current process's PSP which is used by DOS as a process identifier

Call With
AH 51h
Returns:
BX segment of PSP for current process
Notes: DOS uses the current PSP address to determine which process owns files and memory; it corresponds to process identifiers used by other OSs

Under DOS 2.x this function should not be invoked while an INT 28h handler with the Set Critical Error flag

Under DOS 3+ this function does not use any of the DOS internal stacks and may thus be called at any time, even during another INT 21h call

This function is identical to the undocumented function 21 62h, and is supported by OS/2 compatibility box

This call was not documented for DOS 2.x-4.x, but has been documented for DOS 5.0
See Also: 2F 26h,21 50h,21 62h

INT 21h Function 52h — DOS 2+
"SYSVARS" - GET LIST OF LISTS

Determine the address of DOS's internal list of tables and lists. Many undocumented structures are reachable through this list

Call With
AH 52h
Returns
ES:BX pointer to DOS list of lists
Note: This function is partially supported under DOS 2.11 for compatibility box bugs; most pointers are 0000:0000h or 0008:0000h, and the NUL header at 0008:0000h points to FFFF:FFFFh. The implementation of this function is very simple, see Example 9

Format of List of Lists (SysVars):

Offset	Size	Description
-12	WORD	DOS 3.1+ SHARE.EXE retry count, see 21 440Bh
-10	WORD	DOS 3.1+ SHARE.EXE delay count, see 21 440Bh
-8	DWORD	DOS 4.x+ pointer to current disk buffer
-4	WORD	DOS 3.x+ pointer to DOS internal CON input routine When CON is read via a handle, DOS reads an entire line and returns it to the caller a character at a time; the next read operation returns the next character 0000h indicates no unread input
2	WORD	segment of first memory control block
00h	DWORD	pointer to first DPB, see Programmer's Guide, see INT 21 - AH=32h
04h	DWORD	pointer to first System File Table, see below
08h	DWORD	pointer to active CLOCK$ device header, or most recent header if no active CLOCK$ (but bit 3 set) drive with CLOCK$ but (bit 3 set)
0Ch	DWORD	pointer to active CON device header, or most recent header if no active CON (but bit 0 set), such as ANSI.SYS with STDIN but (bit 0 set), such as ANSI.SYS

DOS 2.x—

20	BYTE	number of logical drives in system
21	WORD	maximum bytes/block of any block device
23	DWORD	pointer to first disk buffer (see below)
27	DWORD	pointer to CON device header (not a pointer!)
		NUL is always the first device in DOS's linked list of device drivers (see below for format)

—DOS 3.0—

20	BYTE	number of block devices
21	WORD	maximum bytes/block of any block device
23	DWORD	pointer to first disk buffer (see below)
27	DWORD	pointer to current directory structure (see below)
2B	BYTE	value of LASTDRIVE command in CONFIG.SYS (default=5)
2C	DWORD	pointer to INSTANCE= workspace area
30	WORD	size of INSTANCE= area from CONFIG.SYS
32	DWORD	pointer to FCB table
36	WORD	the /x in FCBS=x,x from CONFIG.SYS
38	BYTE	NUL device driver header (not a pointer!)
		NUL is always the first device in DOS's linked list of device drivers (see below for format)

DOS 3.1/3.3—

20	WORD	maximum bytes per sector of any block device
22	DWORD	pointer to disk buffer info record (see below)
26	DWORD	pointer to current directory structure (see below)
2A	DWORD	pointer to system FCB tables (see below)
2E	WORD	number of additional FCB tables (the /x in the CONFIG.SYS FCBS=x,x)
30	BYTE	number of block devices installed
31	BYTE	number of JOINed drives (bits 6-7), largest of 5 installed block devices and CONFIG.SYS LASTDRIVE= (bits 0-4). Also size of current directory structure array
32	18 BYTEs	actual NUL device driver header (not a pointer!) NUL is always the first device in DOS's linked list of device drivers (see below for format)
44	BYTE	number of JOINed drives

DOS 4.x

20h	WORD	maximum bytes per sector of any block device
22h	DWORD	pointer to disk buffer info record (see below)
26h	DWORD	pointer to current directory structure (see below)
2Ah	DWORD	pointer to system FCB tables (see below)
2Eh	WORD	number of additional FCB tables (the /x in the CONFIG.SYS FCBS=x,x); always 00h for DOS 4.0
30h	BYTE	number of block devices installed
31h	BYTE	number of JOINed drives (bits 6-7), largest of 5 installed block devices and CONFIG.SYS LASTDRIVE= (bits 0-4). Also size of current directory structure array
32h	18 BYTEs	actual NUL device driver header (not a pointer!) NUL is always the first device in DOS's linked list of device drivers (see below for format)
44h	BYTE	number of JOINed drives

35h	WORD	pointer within MS-DOS SYS data segment to list of special program names (see below) (always 0000h for DOS 5.0 to 6.0)
37h	DWORD	pointer to FAR routine for resident IFS utility function (see below) This routine may be called by any IFS driver which does not wish to service functions 20h or 24h–28h itself
3Bh	DWORD	pointer to chain of IFS "installable file system" drivers
3Fh	WORD	the value in BUFFERS=x,y rounded up to multiple of 30 (see DAYS)
41h	WORD	number of lookahead buffers (the y in BUFFERS=x,y) and offsets 3Bh and 3Dh under "DOS 5.0-6.0" should be read
41h	WORD	the x in BUFFERS=x,y
43h	BYTE	boot drive (1=A:)
44	*BYTE*	*01h if 80386+, 00h otherwise*
45h	WORD	extended memory size in K
—DOS 5.0-6.0—		
10h	39 BYTEs	as for DOS 4.x (see above)
37h	DWORD	pointer to SETVER program list or 0000h:0000h
3Bh	WORD	DOS 3.3+ offset in DOS CS of function to EXEC/AX20 control when executing special .COM format
3Dh	WORD	PSP of most recently EXECed program if DOS=HIMEM 0000h if DOS low
3Fh	8 BYTEs	as for DOS 4.x (see above)

Format of memory control block (see also below):

Offset	Size	Description
00h	BYTE	block type: 'M' if last block in chain, otherwise 'Z' (4Dh)
01h	WORD	PSP segment of owner or 0000h if free 0000h if DR DOS XMS UMB 0001h if DR DOS excluded upper memory "block" 0008h if belongs to DOS FFFAh if 386MAX UMB control block FFFDh if 386MAX locked out memory FFFEh if 386MAX UMB; normal area follows its control block
03h	WORD	size of memory block in paragraphs
05h	3 BYTEs	unused
—DOS 2.x,3.x—		
08h	8 BYTEs	unused
—DOS 4+—		
08h	8 BYTEs	ASCII program name (PSP memory block or DR DOS UMB; else garbage until terminated if less than 8 characters)

Notes: The first MCB is a segment (current size + 1).

Under DOS 3.1+, the first memory block is the DOS data segment containing installable device drivers (under DOS 4+ it is divided into subsegments, each with its own memory control block (see below), the first of which is at offset 0000h).

For DOS 5.0+, blocks owned by DOS may have either "SC" or "SD" in bytes 08h and 09h. "SC" is system code or locked out inter-UMB memory, "SD" is system data (device drivers, etc).

Some versions of DR DOS use only seven characters of the program name, placing a NUL in the eighth byte.

Format of MS-DOS 5.0 UMB control block:

Offset	Size	Description
00h	BYTE	type: "M" if last block in chain, 4Dh otherwise
01h	WORD	first available paragraph of UMB if control block at start of UMB, 0000h if control block at end of UMB
03h	WORD	length in paragraphs of following UMB or locked out region
05h	3 BYTEs	unused
08h	8 BYTEs	block type name: "UMB" if start block, "SM" if end block in UMB

Format of DOS 4+ data segment subsegment control blocks:

Offset	Size	Description
00h	BYTE	subsegment type: blocks typically appear in this order "D" device driver "F" device driver appendage "I" IFS (Installable File System) driver "L" LASTDRIVE control block storage area for DOS 5+ "X" FCBS= control block storage area, if present "U" BUFFERS /X workspace area if BUFFERS /X option used) "B" BUFFERS= storage area "A" DOS 5+ CURDIR - current directory structures array storage area "S" STACKS - code and data area if present, see below "I" INSTALL - transient code
01h	WORD	paragraph address (segment start, usually the next paragraph)
03h	WORD	size of subsegment in paragraphs
05h	3 BYTEs	unused
08h	8 BYTEs	for types "D" and "I", base name of file from which the driver was loaded, unused for other types

Format of data at start of STACKS code segment (if present):

Offset	Size	Description
00h	*WORD*	*unknown*
02h	WORD	number of stacks (the /n in STACKS=n,s)
04h	WORD	size of stack control block area (should be 8*n)
06h	WORD	size of each stack (the /s in STACKS=n,s)
08h	DWORD	pointer to STACKS data segment
0Ch	WORD	offset to STACKS data segment of stack control block array
0Eh	WORD	offset to STACKS data segment of last element of that array
10h	WORD	offset to STACKS data segment of the entry in that array for the next stack to be allocated (initially same as value at 0Ch, wraps around to value at 0Eh to the value at 0Ch when hardware interrupts preempt each other)

Note: The STACKS code segment and data area, if present, is located as follows:

DOS 3.2: The code segment address is stored in a word in the IBMBIO segment, seen at 0070:01908h.

DOS 3.3: The code segment address is stored in a word in the DOS data segment which can be found by examining the segment pointers of the vectors for those of interrupts 20h, 28h, 2Ah, 2Fh, 21h, 25h, 26h, 27h, 33h, 74h, 75h, 76h, 77h which have not been redirected by device drivers or TSRs.

DOS 4.x: Identified by stub segment control block type "S" within the DOS data segment.

Format of array elements in STACKS data segment:

Offset	Size	Description
00h	BYTE	status: 00h=free, 01h=in use, 03h=corrupted by overflow of a higher stack
01h	BYTE	not used
02h	WORD	previous SP
04h	WORD	previous SS
06h	WORD	ptr to word at top of stack; new value for SP; the word at the top of the stacks is preset to point back to this control block

SHARE.EXE hooks (DOS 3.1-6.0):

offsets from first System File Table pointed at by [first SFT]-4; see SHARE HOOK C in Chapter 8

Offset	Size	Description
30h	DWORD	*pointer to FAR routine for unknown purpose* Note: not called by MS DOS 3.3; set to 0000h:0000h by SHARE 3.3
34h	DWORD	pointer to FAR routine called on opening file or on call to internal DOS location points at filename; see 21,5D06h Returns: CF clear if successful CF set on error AX = DOS error code (24h; see *21,59h*) Note: SHARE assumes DS=SS=DOS DS and directly accesses DOS internals to get the name of the file just opened
38h	DWORD	pointer to FAR routine called on closing file ES:DI pointer to system file table Note: SHARE does something to every disk record for the
3Ch	DWORD	pointer to FAR routine to close all files for given computer called by 21,5D03h
40h	DWORD	pointer to FAR routine to close all files for given process called by 21,5D04h
44h	DWORD	pointer to FAR routine to close file w/ sharing called by 21,5D02h DS:SI pointer to DOS parameter list; see 21,5D00h DPL=DS:DX pointer to name of file to close Returns: CF clear if successful CF set on error AX = DOS error code (03h) see 21,59h
48h	DWORD call with BX CX:DX SI:AX	pointer to FAR routine to lock region of local file file handle starting offset size Returns: CF set on error AL = DOS error code (21h); see *21,59h* Note: not called if file is marked as remote
4Ch	DWORD call with BX	pointer to FAR routine to unlock region of local file file handle

```
                CX:DX   starting offset
                SI:AX   size
                Returns
                  CF set on error
                    AX    DOS error code (21h) (see 21/59h)
                Note: not called if file opened for network access (see 2F/1108)
10h     DWORD   pointer to FAR routine to check if region is locked
        call with ES:DI pointer to system file table entry for file
                  CX    length of region from current position in file
                  Returns:
                  CF set if any portion of region locked
                    AX    0021h
18h     DWORD   pointer to FAR routine to get open file list entry
                called by 21/5300h
                  ES:DI pointer to DOS private area (see 21/5300h)
                DPL:BX  index of sharing record
                DPL:CX  index of SFT in SFT chain of sharing rec
                Returns:
                  CF set on error or not loaded
                    AX    DOS error code (12h) (see 21/59h)
                          CF clear if successful
                    ES:DI pointer to filename
                    CX    number of locks owned by specified SFT
                    BX    network machine number
                    DX    destroyed
14h     DWORD   pointer to FAR routine for updating FCB from SFT
                call with DS:SI pointer to unopened FCB
                  ES:DI pointer to system file table entry
                Returns:
                  none
                Note: copies following fields from SFT to FCB
                starting cluster of file        08h 14h
                sharing record offset           33h 10h
                file attribute                  04h 11h
1Ah     DWORD   pointer to FAR routine to get first cluster of FCB file
                call with ES:DI pointer to system file table entry
                  DS:SI pointer to FCB
                Returns:
                  CF set if SFT closed or sharing record offsets mismatched
                  CF clear if successful
                          starting cluster number from FCB
1Eh     DWORD   pointer to FAR routine to set file handles for process
        DS:SI   pointer to system file table
                Returns:
                  AX      number of handle in PFT which already uses SFT
                Note: called during open, create of a file
                Note: if SHARE specified and not already loaded
                      see 2F/1000h; SHARE does something to all
                      or SFTs referring to a file which have the same
                file open mode and sharing record
22h     DWORD   pointer to unknown FAR routine
```

		Note: closes various handles referring to file most recently opened
04h	DWORD	pointer to FAR routine to update directory and system related SFT entries
		call with ES:DI pointer to system file table entry for file (see below)
		AX subfunction (apply to each related SFT)
		00h update time stamp (offset 0Dh) and date stamp (offset 0Fh)
		01h update file size (offset 11h) and start cluster (offset 0Bh)
		Sets last accessed cluster fields to start of file if file never accessed
		02h as function 01h, but last accessed fields always changed
		03h do both functions 00h and 02h
		Note: follows pointer at offset 29h to system file table entries
		Note: NOP if opened with no inherit or via FCB

Note: Most of the above hooks (except 04h, 14h, 18h, and 30h) assume either that SS=DOS DS or SS:DS=DOS DS, and directly access DOS internal data

Format of sharing record:

Offset	Size	Description
00h	BYTE	flag
		00h free block
		01h allocated block
		FFh end marker
01h	WORD	size of block
03h	BYTE	checksum of parameters, including NUL
		0 sum of ASCII values is N, checksum is (N+256)+(N%256)
04h	WORD	offset in SHARE's DS of lock record (see below)
06h	DWORD	pointer to start of system file table chain for file
0Ah	WORD	unique sequence number
0Ch	var	ASCIZ full pathname

Format of SHARE.EXE lock record:

Offset	Size	Description
00h	WORD	offset (SHARE's DS) of next lock table in list
02h	DWORD	offset in file of start of locked region
06h	DWORD	offset in file of end of locked region
0Ah	DWORD	pointer to System File Table entry for this file
0Eh	WORD	PSP segment of lock's owner

Format of DOS 2.x system file tables:

Offset	Size	Description
00h	WORD	pointer to next file table, offset = FFFFh if last
04h	WORD	number of files in this table
06h	28h bytes per file	
Offset	**Size**	**Description**
00h	BYTE	number of file handles referring to this file
01h	BYTE	file open mode (see *21/3D*)
02h	BYTE	file attribute
03h	BYTE	drive (0=character device, 1=A, 2=B, etc)
04h	11 BYTEs	filename in FCB format (no path, no period, blank padded)
0Fh	*WORD*	*unknown*
11h	*WORD*	*unknown*
13h	*DWORD*	*file size*
17h	WORD	file date in packed format (see *21/5700*)

19h	WORD	file time in packed format (see *21 5700h*)
1Bh	BYTE	device attribute (see 21 4400h)
character device—		
1Ch	DWORD	pointer to device driver
—block device—		
1Ch	WORD	starting cluster of file
1Eh	WORD	relative cluster in file of last cluster accessed
20h	WORD	absolute cluster number of current cluster
22h	*WORD*	*unknown*
24h	*DWORD*	*current file position*

Format of DOS 3.0 system file tables and FCB tables

Offset	Size	Description
00h	DWORD	pointer to next file table, offset FFFFh if last
04h	WORD	number of files in this table
06h	38h bytes per file	

Offset	Size	Description
00h–21h as in DOS 3.1+ (see below)		
22h	WORD	byte offset of directory entry within sector
		[illegible] packed
24h	DWORD	SHARE.EXE pointer [illegible]
28h	WORD	[illegible]
		[illegible] DOSMGR uses the virtual
		[illegible] number, see *2F 1683h*
2Ah	WORD	[illegible]
[illegible]	[illegible]	[illegible] SFT [illegible]
36h	*WORD*	*apparently always 0000h*

Format of DOS 3.1–3.3x system file tables and FCB tables

Offset	Size	Description
00h	[illegible]	[illegible]
04h	WORD	number of files in this table
06h	35h bytes per file	

Offset	Size	Description
00h	WORD	number of file handles referring to this file
02h	WORD	file open mode (see *21 3Dh*)
		bit 15 set if this file opened via FCB
04h	BYTE	file attribute
05h	WORD	device info word (see 21 4400h)
		bit 15 set if remote file
		bit 14 set means do not set file date/time on closing
		bit 12 set means don't inherit on EXEC
		bits 5-0 drive number for disk files
[illegible]	[illegible]	[illegible] device
		else pointer to DOS Drive Parameter Block
		(see 21 32h)
07h	WORD	starting cluster of file
09h	WORD	file time in packed format (see *21 5700h*)
0Bh	WORD	file date in packed format (see *21 5700h*)
0Dh	DWORD	file size

—system file table—		
15h	DWORD	current offset in file (may be larger than size of file *21/42h* does not check new position)
—FCB table—		
19h	WORD	counter for last I/O to FCB
17h	WORD	counter for last open of FCB (these are separate to determine the times of the latest I/O and open)
19h	WORD	relative cluster within file of last cluster accessed
1Bh	WORD	absolute cluster number of last cluster accessed *(0000h if file never read or written)*
1Dh	WORD	number of sector containing directory entry
1Fh	BYTE	number of dir entry within sector (mod 32)
20h	11 BYTEs	file name in FCB format (no path, period, blank padded)
2Bh	DWORD	SHARE.EXE pointer to previous SFT sharing same file
2Fh	WORD	SHARE.EXE network machine number which opened file (Windows Enhanced mode DOSMGR uses the virtual machine ID as the machine number; see 2F.1683h)
31h	WORD	PSP segment of file's owner (see 21/26h) (first three entries for AUX/CON/PRN contain segment of DOS's startup code; sometimes contains PSP's MCB rather than PSP itself)
33h	WORD	offset within SHARE.EXE code segment of sharing record (see above; 0000h if none)

Format of DOS 4.0-6.0 system file tables and FCB tables:

Offset	Size	Description
00h	DWORD	pointer to next file table (offset = FFFFh if last)
04h	WORD	number of files in this table
06h	3Bh bytes per file	

Offset	Size	Description
00h	WORD	number of file handles referring to this file
02h	WORD	file open mode (see *21/3Dh*) bit 15 set if this file opened via FCB
04h	BYTE	file attributes
05h	WORD	device info word (see 21/4400h) bit 15 set if remote file bit 14 set if treat as EOF (not set file date/time on closing) bit 13 set if named pipe bit 12 set if no inherit bit 11 set if network spooler bits 5-0 drive number for disk files
07h	DWORD	pointer to device driver header if character device else pointer to DOS Drive Parameter Block (see 21/32h) or RFDIR data
0Bh	WORD	starting cluster of file
0Dh	WORD	file time in packed format (see *21/5700h*)
0Fh	WORD	file date in packed format (see *21/5700h*)
11h	DWORD	file size
15h	DWORD	current offset in file

—local file—		
19h	WORD	relative cluster within file of last cluster accessed
1Bh	DWORD	number of sector containing directory entry
1Fh	BYTE	number of dir entry within sector (byte offset/32)
—network redirector—		
19h	DWORD	pointer to REDIRIFS record
1Dh	*3 BYTEs*	*unknown*
—		
20h	11 BYTEs	[illegible] format, no path, period, blank padded
2Bh	DWORD	SHARE.EXE pointer to previous SHARE sharing info file
2Fh	WORD	SHARE.EXE network machine number which opened file (Windows Enhanced mode DOSMGR uses the [illegible] as the machine number; see *2F 1083h*)
31h	WORD	PSP segment of file's owner (see 21/26h) (first three entries for AUX, CON, PRN contain segment of IO.SYS startup code)
33h	WORD	offset within SHARE.EXE code segment of sharing record (see above); 0000h if none
35h	WORD	(local) absolute cluster number of last cluster accessed (*redirector: unknown*)
37h	DWORD	pointer to IFS driver for file; 00000000h if native DOS

Format of current directory structure (CDS) (array, LASTDRIVE entries):

Offset	Size	Description
00h	67 BYTEs	ASCIZ path (e.g. "A:\PATH"), local or "\\MACHINE\PATH" (network)
43h	WORD	drive attributes (see also note below and 21 5F07h) [illegible] physical drive / physical if 0 00 installable file system if 11 / [illegible] JOIN'd / [illegible] SUBST'd / (set above is true path that would be valid if not under SUBST or JOIN) / 7 redirector, but not network (e.g. CD ROM)
45h	DWORD	pointer to Drive Parameter Block for drive (see 21/32h)
—local drives—		
49h	WORD	starting cluster of current directory (0000h if root, FFFFh if never accessed)
4Bh	*WORD*	*apparently always FFFFh*
4Dh	*WORD*	*apparently always FFFFh*
—network drives—		
49h	DWORD	pointer to Current Directory or REDIRIFS record, or FFFFh:FFFFh
4Dh	*WORD*	*stored user data from 21 5F03h*
4Fh	WORD	[illegible] offset into path of backslash corresponding to root directory for drive (i.e. number of characters to hide from the GET DIR string; for GET DIR calls normally set to 2 to hide the [illegible] for drives SUBSTed, JOINed, and networks [illegible] the appropriate portion of the true path is visible to the user)
—DOS 4+—		
51h	*BYTE*	*unknown, used by network*
52h	DWORD	pointer to IFS driver, or -1 if none; 00000000h if native DOS
56h	*WORD*	*unknown*

Notes: The path for invalid drives is normally set to "X:" but may be empty after JOIN or SUBST in DR DOS 5.0 or NET USE x: /D in older LAN versions

Normally only one of bits 13&12 may be set together with bit 14, but DR DOS 5.0 uses other combinations (see below)

Format of DR-DOS 5.0-6.0 current directory structure entry (array):

Offset	Size	Description
00h	67 BYTEs	ASCIIZ path name of actual root directory for this logical drive
43h	WORD	drive attributes 1000h SUBSTed drive *2000h JOINed drive* 4000h physical drive 5000h ASSIGNed drive 7000h JOINed drive 8000h network drive
45h	BYTE	physical device number (0="A:") if this logical drive is valid
46h	*BYTE*	*apparently this is for JOIN and ASSIGN*
47h	WORD	cluster number of start of parent directory (0000h if root)
49h	WORD	cluster number of current directory in parent directory
4Bh	WORD	cluster number of start of current directory
4Dh	*WORD*	*used for media change detection*
4Fh	WORD	cluster number of SUBST/JOIN'ed root directory 0000h if physical root directory

Format of device driver header:

Offset	Size	Description
00h	WORD	pointer to next driver (offset FFFFh if last driver)
04h	WORD	device attributes Character device bit 15 set bit 14 IOCTL supported (see AX=4402h,4403h) bit 13 DOS 3.x output until busy supported bit 12 reserved bit 11 DOS 3.x OPEN/CLOSE/RemMedia calls supported bits 10-8 reserved bit 7 (DOS 5.x) Generic IOCTL check call supported (see AX=4410h, command 19h) bit 6 (DOS 3.2+) Generic IOCTL call supported (see AX=4410h, command 13h) bit 5 reserved bit 4 device is special (as INT 29h "fast console output") bit 3 device is CLOCK$ (all reads/writes use transfer record described below) bit 2 device is NUL bit 1 device is standard output bit 0 device is standard input Block device bit 15 clear bit 14 IOCTL supported bit 13 non-IBM format bit 12 reserved bit 11 DOS 3.x OPEN/CLOSE/RemMedia calls supported

bit 10 reserved
bit 9 direct I/O not allowed
(set by DOS 3.3 DRIVER.SYS for "new" drives)
bit 8 unknown media (set by DOS 3.3 DRIVER.SYS for "new drives")
bit 7 DOS 5+: Generic IOCTL check call supported
(command 19h)
bit 6 DOS 3.2+: Generic IOCTL call supported
(command 13h)
implies support for commands 17h and 18h
bits 5-2 reserved
bit 1 DOS 3.31+: driver supports 32-bit sector addressing
bit 0 reserved

06h	WORD	device strategy entry point (call with ES:BX pointer to request header (see 2F/0802h)
08h	WORD	device interrupt entry point

—character device—

0Ah	8 BYTEs	blank-padded character device name

—block device—

0Ah	BYTE	number of subunits (drives) supported by driver
0Bh	7 BYTEs	unused

—

12h	WORD	(CD-ROM driver) reserved (must be 0000h)
14h	BYTE	(CD-ROM driver) Int 2Fh subfunction (must initially be 00h)
15h	BYTE	(CD-ROM driver) number of units
16h	6 BYTEs	(CD-ROM driver) signature 'MSCD0nn' where 'nn' is version (currently '00')

Format of CLOCK$ transfer record:

Offset	Size	Description
00h	WORD	number of days since 1 Jan 1980
02h	BYTE	minutes
03h	BYTE	hours
04h	BYTE	hundredths of second
05h	BYTE	seconds

Format of DOS 2.x disk buffer:

Offset	Size	Description
00h	DWORD	pointer to next disk buffer (offset = FFFFh if last least recently used buffer is first in chain
04h	BYTE	drive (0=A, 1=B, etc), FFh if not in use
05h	3 BYTEs	*apparently unused; seem always to be 00h 00h 01h*
08h	WORD	logical sector number
0Ah	BYTE	number of copies (zero for non-FAT sectors)
0Bh	BYTE	sectors/FAT (between copies if multiple copies to be written
0Ch	DWORD	pointer to DOS Drive Parameter Block (see 21/32h)
10h		buffered data

Format of DOS 3.x disk buffer:

Offset	Size	Description
00h	DWORD	pointer to next disk buffer (offset = FFFFh if last least recently used buffer is first in chain
04h	BYTE	drive (0=A, 1=B, etc), FFh if not in use

05h	BYTE	flags *bit 7 unknown* bit 6 buffer dirty bit 5 buffer has been referenced *bit 4 unknown* bit 3 sector in data area bit 2 sector in a directory, either root or subdirectory bit 1 sector in FAT *bit 0 boot sector*
06h	WORD	logical sector number
08h	BYTE	number of copies to write (1 for non-FAT sectors)
09h	BYTE	sectors/FAT between copies of multiple copies to be written
0Ah	DWORD	pointer to DOS Drive Parameter Block (see INT 21/AH=32h)
0Eh	*WORD*	*apparently unused (at most always 0)*
10h	buffered data	

Format of DOS 4.00 (pre UR 25066) disk buffer info:

Offset	Size	Description
00h	DWORD	pointer to next disk buffer (last chain reads -1)
04h	WORD	number of disk buffer hash chains (referred from NDBC in SDA)
06h	DWORD	pointer to look-ahead buffer (-1 if not present)
0Ah	WORD	number of look-ahead sectors (also stored in BUFFERS=xx)
0Ch	BYTE	00h if buffers in EMS, -1 if not
0Dh	WORD	EMS handle for buffers (zero if not in EMS)
0Fh	WORD	EMS physical page frame segment for buffers (usually 253)
11h	*WORD*	*apparently always 0001h*
13h	WORD	segment of EMS physical page frame
15h	*WORD*	*apparently always 0*
17h	*4 WORDs*	*EMS physical page mapping information*

Format of DOS 4.01 (from UR 25066 Corrective Services Disk on) disk buffer info:

Offset	Size	Description
00h	DWORD	pointer to next disk buffer (last chain reads -1)
04h	WORD	number of disk buffer hash chains (referred from NDBC in SDA)
06h	DWORD	pointer to look-ahead buffer (-1 if not present)
0Ah	WORD	number of look-ahead sectors (also stored in BUFFERS=xx)
0Ch	BYTE	00h if buffers in EMS, -1 if not (UR 25066 format)
0Dh	*WORD*	*EMS handle for BUFFERS (zero if not in XM)*
0Fh	*WORD*	*EMS physical page frame segment for EMS (zero if not in XM)*
11h	*WORD*	*EMS physical page mapping information (-1 if not in XM)*
13h	*WORD*	*EMS physical page frame segment for EMS (zero if not in XM)*
15h	*BYTE*	*number of EMS page frame physical pages used (zero if not in XM)*
16h	WORD	segment of 4096-byte workspace buffer allocated in upper memory if BUFFERS/XS or /XD options in effect, possibly to avoid DMA into EMS
18h	WORD	EMS handle for workspace buffer (zero if not in EMS)
1Ah	WORD	EMS physical page frame segment for buffers (usually 253)
1Ch	*WORD*	*appears always to be 0001h*
1Eh	WORD	segment of EMS physical page frame
20h	*WORD*	*appears always to be zero*
22h	BYTE	00h if /XS, 01h if /XD, FFh if BUFFERS not in EMS

Format of DOS 4.x disk buffer hash chain head (array, one entry per chain):

Offset	Size	Description
	WORD	(EMS) logical page number (FFFFh if chain is resident, FFFEh if not in EMS)
	DWORD	segment:offset of least recently used buffer header (all buffers on this chain are in the same segment)
06h	BYTE	number of dirty buffers on this chain
07h	BYTE	reserved (00h)

Notes: [illegible] where N is the sector's address modulo number of disk buffer chain heads (NDBCH); 0 <= N <= NDBCH-1

[illegible] pointer is relative to start of EMS page

This structure is in main memory even if the buffers are in EMS

Format of DOS 4.0/4.0.6 disk buffer:

Offset	Size	Description
00h	WORD	forward pointer (offset only) to next least recently used buffer
02h	WORD	backward pointer (offset only)
04h	BYTE	drive (0=A:, 1=B:, etc.; FFh if not in use)
05h	BYTE	flags bit 7: remote buffer bit 6: buffer dirty bit 5: buffer has been referenced bit 4: search data buffer contains valid info if remote buffer bit 3: sector in data area bit 2: sector in a directory, either root or subdirectory bit 1: sector in FAT bit 0: reserved
06h	DWORD	logical sector number
0Ah	BYTE	number of copies to write for FAT sectors, same as number of FATs for data and directory sectors, usually 1
0Bh	WORD	[illegible] sectors between copies of FAT sectors
0Dh	DWORD	[illegible] DOS 3.x Parameter Block, see AX=3201h above
11h	WORD	[illegible] buffer, see Notes above
13h	BYTE	reserved
14h	buffered data	

Note: For DOS 4.x, all buffered sectors [illegible] this structure has a value computed as the sum of [illegible] NDBCH) on the same doubly linked circular chain; for DOS 5+, only a single circular chain exists

[illegible] segment being the same for all buffers in the chain

See BUFFERS (in Chapter 8)

Format of DOS 5+ disk buffer info:

Offset	Size	Description
00h	WORD	[illegible] buffer header may be in HMA (see above)
04h	WORD	[illegible] DOS 5+ linked sectors, see offset 00h; points directly at the only buffer chain)
06h	DWORD	[illegible] (FFFFFFFFh if interval not present
0Ah	WORD	number of [illegible] zero if no BUFFERS=xx,y

0Ch	BYTE	buffer location 00h base memory, no workspace buffer 01h HMA, workspace buffer in base memory
0Dh	DWORD	pointer to disk segment workspace buffer in base memory
11h	3 BYTEs	apparently unused
14h	WORD	unknown
16h	*BYTE*	*unknown, counter or flag*
17h	BYTE	temporary storage for user memory allocation strategy during EXEC
18h	BYTE	unknown counter
19h	BYTE	bit flags bit 0 unknown bit 1 SWITCHES=/W specified in CONFIG.SYS (don't auto-load WINA20.386 when MS Windows 3.0 starts) bit 2 in EXEC state (21 4B05h)
1Ah	WORD	unknown, offset used only during 21 4B05h
1Ch	BYTE	bit 0 set if UMB MCB chain linked to normal MCB chain
1Dh	WORD	minimum paragraphs of memory required by program being EXECed
1Fh	WORD	segment of first MCB in paragraphs, or top blocks of 1111h if DOS memory chain in base 640K only (the first UMB MCB is usually at 9111h, locking out wide memory with a DOS-owned memory block
21h	WORD	paragraph of start of most recent MCB chain search

Format of IFS driver list:

Offset	Size	Description
00h	DWORD	pointer to next driver header
04h	8 BYTEs	IFS driver name (8 bytes, padded with spaces) as used by FDISK/CONFIG.SYS
0Ch	*4 BYTEs*	*unknown*
10h	DWORD	pointer to IFS utility function entry point (see below) call with ES:BX pointer to IFS request (see below)
14h	WORD	offset to redirector's segment of driver entry point *possibly more*

Call IFS utility function entry point with

AH 20h miscellaneous functions
- AL = 00h get date
  - Returns:
    - CX year
    - DH month
    - DL day
- AL = 01h get process ID and computer ID
  - Returns:
    - BX current PSP segment
    - DX active network machine number
- AL = 05h get file system info
  - ES:DI pointer to 16-byte info buffer
  - Returns
    - buffer filled

Offset	Size	Description
00h	2 BYTEs	unused

```
?       WORD        seconds of SFTs' actual counts over the first two file tables arrays
04      WORD        number of FCB table entries
06      WORD        number of protected FCBs
8       6 BYTEs     unused
WORD    largest sector size supported
  AL = 00h get machine name
            ES:DI       pointer to 18 byte buffer for name
       Returns
            buffer filled with name starting at offset 02h
  AL = 08h get sharing retry count
       Returns
            BX          sharing retry count
  AL = other
       Returns
            CF set
    AH = 20h
         AL = 00h


         AL = other
           Returns
             CF set
    AH = 21h get redirection state
         BH          ?ps
         Returns
             BH          state
    AH = 22h appears to be a time calculation
         AL = 00h
            set CF
    AH = 23h
    AH = 24h
         DS:SI
         ES:DI
         Returns
           AL
    AH = ?Sl
         DS:SI
         ES:DI
         Returns
           Set CF
    AH = 26h
         Returns


    AH = 27h
    AH = 28h
```

Note: IFS drivers which do not wish to [illegible] AH = 20h or 24h–28h may pass them on to the default handler pointed at by INT 2Fh.

Format of IFS request block:

Offset	Size	Description
00h	WORD	total size in bytes of request
02h	BYTE	class of request

		02h unknown
		03h redirection
		04h unknown
		05h file access
		06h convert error code to string
		07h unknown
03h	WORD	returned DOS error code
05h	BYTE	IFS driver exit status
		00h success
		01h unknown
		02h unknown
		03h unknown
		04h unknown
		FFh internal failure
06h	*16 BYTEs*	*unknown*
—request class 02h—		
16h	BYTE	function code
		04h unknown
17h	*BYTE*	*apparently unused*
18h	*DWORD*	*pointer to unknown item*
1Ch	*DWORD*	*pointer to unknown item*
20h	*2 BYTEs*	*unknown*
—request class 03h—		
16h	BYTE	function code
17h	*BYTE*	*unknown*
18h	*DWORD*	*pointer to unknown item*
1Ch	*DWORD*	*pointer to unknown item*
22h	*WORD*	*unknown returned value*
24h	*WORD*	*unknown returned value*
26h	*WORD*	*unknown returned value*
28h	*BYTE*	*unknown returned value*
29h	*BYTE*	*apparently unused*
—request class 04h—		
16h	*DWORD*	*unknown pointer*
1Ah	*DWORD*	*unknown pointer*
—request class 05h—		
16h	BYTE	function code
		01h flush disk buffers
		02h get disk space
		03h MKDIR
		04h RMDIR
		05h CHDIR
		06h delete file
		07h rename file
		08h search directory
		09h file open/create
		0Ah LSEEK
		0Bh read from file
		0Ch write to file
		0Dh lock region of file

01h commit close file
0Eh get set file attributes
10h printer control
11h unknown
12h process termination
13h unknown

—class 05h function 01h—

17h	*BYTE*	[illegible]
1Eh	*DWORD*	[illegible]
22h	*4 BYTE*	[illegible]
26h	*BYTE*	*unknown*
27h	*BYTE*	*unknown*

—class 05h function 02h—

17h	*BYTE*	*unknown*
1Eh	*DWORD*	*unknown pointer*
	4 BYTE	*unknown*
26h	WORD	returned total clusters
28h	WORD	returned sectors per cluster
2Ah	WORD	returned bytes per sector
2Ch	WORD	returned available clusters
2Eh	*BYTE*	*unknown returned value*
2Fh	*BYTE*	*unknown*

—class 05h functions 03h,04h,05h—

17h	*BYTE*	*unknown*
1	*DWORD*	[illegible]
	4 B	[illegible]
0	DWORD	[illegible]

—class 05h function 06h—

17h	*BYTE*	[illegible]
1Eh	*DWORD*	[illegible]
22h	*4 BYTE*	[illegible]
26h	WORD	attributes
28h	DWORD	pointer to filename

—class 05h function 07h—

17h	*BYTE*	[illegible]
1Eh	*DWORD*	[illegible]
22h	*4 BYTE*	[illegible]
26h	WORD	[illegible]
28h	DWORD	[illegible]
2Ch	DWORD	pointer to destination filespec

—class 05h function 08h—

		[illegible]
1Eh	*DWORD*	[illegible]
22h	*4 BYTE*	[illegible]
26h	BYTE	00h FINDFIRST 01h FINDNEXT
28h	DWORD	pointer to FindFirst search data + 01h at FINDNEXT
2Ch	WORD	search attribute at FINDFIRST
2Eh	DWORD	pointer to filespec at FINDFIRST

—class 05h function 09h—

17h	*BYTE*	*unknown*

1Eh	*DWORD*	*unknown pointer*
22h	DWORD	pointer to IFS open file structure (see below
26h	*WORD*	*unknown* } *(on files, specify open to create, whether or*
28h	*WORD*	*unknown* } *not to truncate*
2Ah	*4 BYTEs*	*unknown*
2Eh	DWORD	pointer to filename
32h	*4 BYTEs*	*unknown*
36h	WORD	file attributes on call
		unknown returned value
38h	*WORD*	*unknown returned value*

—class 05h function 0Ah—

17h	*7 BYTEs*	*unknown*
1Eh	*DWORD*	*unknown pointer*
22h	*DWORD*	*pointer to IFS open file structure (see below)*
26h	BYTE	seek type: 02h from end
28h	DWORD	offset on call
		returned new absolute position

—class 05h functions 0Bh,0Ch—

17h	*7 BYTEs*	*unknown*
1Eh	*DWORD*	*unknown pointer*
22h	DWORD	pointer to IFS open file structure (see below
28h	WORD	number of bytes to transfer
		returned bytes actually transferred
2Ah	DWORD	transfer address

—class 05h function 0Dh—

17h	*7 BYTEs*	*unknown*
1Eh	*DWORD*	*unknown pointer*
22h	*DWORD*	*pointer to IFS open file structure (see below)*
26h	*BYTE*	*file handle*
27h	*BYTE*	*apparently unused*
28h	*WORD*	*unknown*
2Ah	*WORD*	*unknown*
2Ch	*WORD*	*unknown*
2Eh	*WORD*	*unknown*

—class 05h function 0Eh—

17h	*7 BYTEs*	*unknown*
1Eh	*DWORD*	*unknown pointer*
22h	DWORD	pointer to IFS open file structure (see below
26h	BYTE	00h commit file
		01h close file
27h	*BYTE*	*apparently unused*

—class 05h function 0Fh—

17h	*7 BYTEs*	*unknown*
1Eh	*DWORD*	*unknown pointer*
22h	*4 BYTEs*	*unknown*
26h	BYTE	02h GET attributes
		03h PUT attributes
27h	*BYTE*	*apparently unused*
28h	*17 BYTEs*	*unknown*
3Ah	*WORD*	*search attribute*
36h	DWORD	pointer to filename

3Ah	*WORD*	*(GET) unknown returned value*
	WORD	*(GET) unknown returned value*
	WORD	*(GET) unknown returned value*
40h	WORD	*(GET) unknown returned value*
42h	WORD	(SET) new attributes
		(GET) returned attributes

class 05h function 10h—

	BYTEs	*unknown*
	DWORD	*unknown pointer*
	DWORD	pointer to IFS open file structure (see below)
	WORD	*unknown*
	DWORD	*unknown pointer*
	WORD	*unknown*
	BYTE	*unknown*
1	BYTE	subfunction
		01h get printer setup
		[illegible]
		[illegible]
		[illegible]
		06h unknown
		07h unknown
		21h set printer setup

class 05h function 11h—

	BYTE	[illegible]
1Eh	*DWORD*	*unknown pointer*
[illegible]	DWORD	pointer to IFS open file structure (see below)
[illegible]	BYTE	subfunction
	BYTE	*apparently unused*
	[illegible]	[illegible]
	WORD	*unknown*
	WORD	[illegible]
[illegible]	*BYTE*	[illegible]
[illegible]	*BYTE*	[illegible]

class 05h function 12h—

17h	*15 BYTEs*	*apparently unused*
[illegible]	WORD	PSP [illegible]
28h	BYTE	type of process termination
29h	*BYTE*	*apparently unused*

class 05h function 13h—

17h	*15 BYTEs*	*apparently unused*
26h	WORD	PSP segment

—request class 06h—

[illegible]	DWORD	[illegible] corresponding to error code at 03h
1Ah	*BYTE*	*unknown returned value*
1Bh	BYTE	unused

—request class 07h—

16	DWORD	[illegible]
1Ah	*BYTE*	[illegible]
[illegible]	*BYTE*	[illegible]

Format of IFS open file structure:

Offset	Size	Description
00h	WORD	unknown
02h	WORD	device info word
04h	WORD	file open mode

06h	*WORD*	*unknown*
08h	WORD	file attributes
0Ah	WORD	owner's network machine number
0Ch	WORD	owner's PSP segment
0Eh	DWORD	file size
12h	DWORD	current offset in file
16h	WORD	file time
18h	WORD	file date
1Ah	11 BYTEs	filename in FCB format
25h	*WORD*	*unknown*
27h	WORD	last value of SI on address into word at [first table entry + segment &1000h]
29h	3 WORDs	network info from SFT
2Fh	*WORD*	*unknown*

Format of one item in DOS 4+ list of special program names:

Offset	Size	Description
00h	BYTE	length of name (00h is end of list)
01h	N BYTEs	name in format name.ext
N	2 BYTEs	DOS version to return for program (major,minor) or 0
		see 21-30h, 21-122Dh

—DOS 4 only—

N+2	BYTE	[illegible]

Note: If the name of the executable for the program making the DOS "get version" call matches one of the names in this list, DOS returns the specified version rather than the true version number.

INT 21h Function 53h — DOS 2+

Translate Bios Parameter Block To Drive Parameter Block

Computes the information for a Drive Parameter Block from the information in the given BIOS Parameter Block

Call With

AH	53h
DS:SI	pointer to BIOS Parameter Block, see below
ES:BP	pointer to buffer for Drive Parameter Block, see 21-32 for format

Returns

ES:BP buffer filled

Note: For DOS 3.x, if cluster at which FAT starts is >FFFFh, sets word at [ES:BP+0Fh] to FFFFh; if number of clusters is >FFFEh, sets it to FFFFh (unknown).

Format of BIOS Parameter Block:

Offset	Size	Description
00h	WORD	number of bytes per sector
02h	BYTE	number of sectors per cluster
03h	WORD	number of reserved sectors at start of disk
05h	BYTE	number of FATs
06h	WORD	number of entries in root directory
08h	WORD	total number of sectors for DOS 4+, set to zero if partition >32M, the next DWORD at 15h to actual number of sectors
0Ah	BYTE	media ID byte
0Bh	WORD	number of sectors per FAT

—DOS 3+—		
0Dh	WORD	number of sectors per track
0Fh	WORD	number of heads
11h	DWORD	number of hidden sectors
15h	6 BYTEs	reserved
—DOS 4+ —		
1Bh	DWORD	total number of sectors (if word at 08h contains zero)
1Fh	*6 BYTEs*	*unknown*
25h	WORD	number of cylinders
27h	BYTE	device type
28h	WORD	device attributes (removable or not, etc)

INT 21h Function 55h — DOS 2+
CREATE CHILD PSP

Create a new Program Segment Prefix with the specified amount of available memory, and place it at a given location

Call With
- AH — 55h
- DX — segment address to create new PSP
- SI — (DOS 3+) number of paragraphs desired (if DX=0002h)

Returns
- CF — (DOS 3+) set on error
- AX — (DOS 3+) error code (if CF set)

Notes: This function creates a child PSP (the "old" PSP), makes an exact copy of the current PSP, the new PSP is then set to the current PSP, and the old PSP is set to point to the new PSP. The DOS handle count for each inherited file is incremented

(DOS 2+) The current PSP is set to the segment in DX

(DOS 3+) "Non-inherited" file handles are marked as closed in the child PSP

See Also: 21/26h, 21/50h

INT 21h Function 56h — DOS 2+
"RENAME" — RENAME FILE

Make the specified file or directory also be known by another name, or allowing wildcards in both source and destination when invoked via 21/5D00h

Call With
- AH — 56h
- DS:DX — pointer to ASCIIZ name of existing file (no wildcards, but see below)
- ES:DI — pointer to ASCIIZ new filename (no wildcards)
- CL — attribute mask (server call only; see below)

Returns
- CF — clear if successful
- CF — set on error
- AX — error code (02h, 03h, 05h, 11h) (see 21/59h)

Notes: This function allows a file to be moved between directories on a single logical volume

Open files should not be renamed

DOS 3+ allows renaming of directories

For DOS 3+, wildcards are allowed if invoked via 21/5D00h, in which case error 12h (no more files) is returned on success, and both source and destination specs must be canonical (as returned by 21/60h). Wildcards in the destination result in the corresponding char of each source file being retained. Under DOS 3.x, the usual wildcard in the destination is "*.*" or equivalent. When invoked via 21/5D00h, only those files matching the attribute mask in CL are renamed

See Also: *21 717*, 21 5D00h, 21 60h

INT 21h Functions 5702h-5705h — DOS 4.x, OS/2, Chicago
EXTENDED FILE ATTRIBUTE FUNCTIONS

In the DOS 4.xx, OS/2 1.x, and higher, 21 5702 gets the Extended Attributes (EAs) for a file, corresponding to the OS/2 DosQueryPathInfo and DosQueryFileInfo API functions. Likewise, 21 5703 sets the EAs correspondingly to DosSetPathInfo and DosSetFileInfo. Programs that hook the normal MS-DOS 21/57 Get/Set File Date/Time function should probably also hook these OS/2 EA functions. For more information see ch.pter 4 and data on logical drives.

In DOS 4.x only, *not* DOS 5.xx or 6.xx, 21 5703 and 21 5705 can update EAs. 21 5704 has been reported in DOS 4.xx as both "Truncate Open File to Zero Length and Set Extended Attributes". In DOS 4.xx, 21 5703 and 21 5704 issue a 21 1120 call to IBMDOS.COM. Under "Chicago" (DOS 7 Windows 4.x), 21 5704 and 21 5705 call the INT 2Fh functions of the Win32 GetFileTime and SetFileTime API functions. Preliminary Chicago documentation marks 21 57's functions 2 and 3 as "reserved", with stubs provided for the two OS/2 EA functions.

INT 21h Function 5D00h — DOS 3.1+
SERVER FUNCTION CALL

Execute a specified INT 21h call using the sharing rules for the specified network machine number and process ID.

Call With

AX 5D00h
DS:DX pointer to DOS parameter list (see below)
DPL contains all register values for a call to INT 21h

Returns

as appropriate for function to be executed

Notes: This function does not check the specified values for ANY one of the parameters passed to the system.

The DOS call executes using specified computer ID and process ID, sharing delays are skipped, a special scanning mode is established, wildcards are enabled for DELETE (21 41h) and RENAME (21/56h), and an extra file attribute parameter is enabled for OPEN (*21 3Dh*), DELETE (21/41h), and RENAME (21/56h).

Functions which take file pathnames accept special values as returned by 21 60h when invoked by this method, this is apparently to prevent multiple file forwarding.

See Also: *21 3Dh*, 21/41h, 21/56h, 21 60h

Format of DOS parameter list:

Offset	Size	Description
00h	WORD	AX
02h	WORD	BX
04h	WORD	CX
06h	WORD	DX
08h	WORD	SI
0Ah	WORD	DI
0Ch	WORD	DS
0Eh	WORD	ES
10h	WORD	reserved (0)
12h	WORD	computer ID (0000h for current system)
14h	WORD	process ID (PSP segment of specified computer)

Note: Under Windows Enhanced mode the computer ID is the virtual machine ID (see *21 1684h*)

INT 21h Function 5D01h — DOS 3.1+
COMMIT ALL FILES FOR SPECIFIED COMPUTER/PROCESS

Flush file buffers and update the directory entry for each file which has been written to since opening or the last commit

Call With
- AX = 5D01h
- DS:DX = pointer to DOS parameter list (see 21/5D00h) (only computer ID and process ID fields used)

Returns
- CF set on error
  - AX = error code (see 21/59h)
- CF clear if successful

Notes: This function flushes file buffers and updates directory entries for each file which has been written to if the file is remote (calls 21/1107h)

Some programs fill in the process ID but stored but ignored under DOS 3.3

See Also: 21/0Dh, 21/68h, 21/1107h

INT 21h Function 5D02h — DOS 3.1+
SHARE.EXE CLOSE FILE BY NAME

Close a file given as fully qualified name

Call With
- AX = 5D02h
- DS:DX = pointer to DOS parameter list (see 21/5D00h) (only fields DS, computer ID, and process ID used)
- DPL's DS:DX pointer to ASCIIZ name of file to close

Returns:
- CF set on error
  - AX = error code (see 21/59h)
- CF clear if successful

Notes: This function returns an error unless SHARE is loaded (it calls SysFileTable 28h) (see 21/52h)

The name must be a canonicalized pathname such as is returned by 21/60h

See Also: 21/3Eh, 21/5D03h, 21/5D04h, 21/60h

INT 21h Function 5D03h — DOS 3.1+
SHARE.EXE CLOSE ALL FILES FOR GIVEN COMPUTER

Close all files on this computer (using a particular network machine number)

Call With
- AX = 5D03h
- DS:DX = pointer to DOS parameter list (see 21/5D00h) (only computer ID used)

Returns
- CF set on error
  - AX = error code (see 21/59h)
- CF clear if successful

Note: This function returns an error unless SHARE is loaded (it calls SysFileTable 30h) (see 21/52h)

See Also: 21/5D02h, 21/5D04h

INT 21h Function 5D04h — DOS 3.1+
SHARE.EXE - CLOSE ALL FILES FOR GIVEN PROCESS

Close all files opened by a particular process

Call With
AX 5D04h
DS:DX pointer to DOS parameter list (see INT 21/5D00h) containing process ID and process ID locks used

Returns:
CF set on error
AX error code (see *INT 21/59h*)
CF clear if successful

Note: This function is used by NETBIOS to release all locks held by a terminating process (see INT 21/52h)

See Also: INT 21/5D02h, INT 21/5D03h

INT 21h Function 5D05h — DOS 3.1+
SHARE.EXE - GET OPEN FILE LIST ENTRY

Returns the address of the DOS copy of the specified entry in the DOS SFT maintained for SHARE's benefit (undocumented data structures)

Call With
AX 5D05h
DS:SI pointer to DOS parameter list (see INT 21/5D00h)
DPL's BX index of sharing record (see INT 21/52h)
DPL's CX index of SFT in sharing record's SFT list

Returns
CF clear if successful
ES:DI pointer to ASCIIZ filename
BX network machine number of SFT's owner
CX number of locks held by SFT's owner
CF set if other index out of range
AX 0012h (no more files)

Notes: This function is used by SHARE to enumerate all files open in the system (see also INT 21/52h, INT 21/B7h)
This function is called by INT 21/5D00h after the DOS swappable data area has been updated (see INT 21/5D06h)

See Also: INT 21/5D00h

INT 21h Function 5D06h — DOS 3.0+
GET ADDRESS OF DOS SWAPPABLE DATA AREA

Returns information about the location and size of the DOS data area which must be preserved across a DOS call if DOS is to be reentered

Call With
AX 5D06h

Returns
CF set on error
AX error code (see *INT 21/59h*)
CF clear if successful
DS:SI pointer to DOS swappable data area
CX size of DOS swappable data area if called by server
DX size of DOS swappable data area if called by DOS

Notes: [illegible] flag is used in conjunction with the InDOS flag (see 21/34h) to determine when it is safe to enter DOS from a TSR

[illegible] was the use of functions 50h-54h from INT 28h under DOS 2.x by [illegible] correct stack

[illegible] to critical sections entering DOS unless DOS is in a critical section delimited by 2A/80h and 2A/81h/82h

[illegible] DOS 4.x 21/5D0Bh should be used instead of this function; the DOS 5+ swappable data area is also described under that call

SHARE [illegible] DOS 3+ does determine the SDA to use by examining the byte at offset 0Bh [illegible] DOS 3.x [illegible] see INT 21h, AX=1205h). A value of 00h indicates a DOS 3.x SDA, [illegible] DOS 4.0 [illegible] values indicate DOS 3.3 or later. See PCMAG.ASM chapter 4

See Also: 21/5D0Bh, 2A/80h, 2A/81h, 2A/82h

Format of DOS 3.10-3.30 Swappable Data Area:

Offset	Size	Description
00	5 WORDs	[illegible] to critical sections (not actually part of the SDA)
0A	BYTE	critical error flag
0Bh	BYTE	InDOS flag (count of active INT 21h calls)
0Ch	BYTE	[illegible] which critical error occurred or FFh
0Dh	BYTE	locus of last error
0Eh	WORD	extended error code of last error
10h	BYTE	suggested action for last error
11h	BYTE	class of last error
12h	DWORD	ES:DI pointer for last error
16h	DWORD	current DTA
1Ah	WORD	current PSP
1Ch	WORD	stores SP across an INT 23h
1Eh	WORD	return code from last process termination (fetched after reading with 21/4Dh, e.g. by COMMAND.COM)
20h	BYTE	current drive
21h	BYTE	extended break flag
-remainder need only be swapped if in DOS-		
22h	WORD	value of AX on call to INT 21h
24h	WORD	PSP segment for sharing, network
26h	WORD	[illegible] to DOS data area for sharing, network (0000h=caller
28h	WORD	[illegible] stack for old system data area when allocating memory
2Ah	WORD	[illegible] stack found when allocating memory
2Ch	WORD	[illegible] stack found when allocating memory
2Eh	WORD	[illegible] of machines used only during initialization
30h	WORD	*unknown*
32h	FLAG	INT 24h returned Fail
33h	FLAG	bit flags for allowable actions on INT 24h
34h	FLAG	*unknown flag*
35h	FLAG	FFh if Ctrl-Break termination, 00h otherwise
36h	FLAG	*unknown flags*
37h	FLAG	*apparently not referenced*
38h	BYTE	day of month
39h	BYTE	month
3Ah	WORD	year - 1980
3Ch	WORD	number of days since 1-1-1980

34h	BYTE	day of week (0 for Sunday)
35h	*BYTE*	*working SFT pointer at SDA+24 (0=invalid*
36h	BYTE	safe to call INT 28h if nonzero
37h	BYTE	flag: if nonzero, INT 24h abort turned into INT 24h fail (set only during process termination)
38h	26 BYTEs	device driver request header (see 21/0802)
52h	DWORD	pointer to device driver entry point (used in calling driver)
56h	22 BYTEs	device driver request header
66h	22 BYTEs	device driver request header
82h	BYTE	type of PSP copy (00h=simple for 21/26h, FFh=make child)
83h	*BYTE*	*apparently not referenced by kernel*
84h	3 BYTEs	24-bit user number (see 21/3Dh)
87h	BYTE	OEM number (see 21/30h)
88h	*2 BYTEs*	*unknown*
8Ah	6 BYTEs	CLOCK$ transfer record (see 21/52h)
90h	*BYTE*	*buffer for single-byte I/O functions*
91h	*BYTE*	*apparently not referenced by kernel*
92h	128 BYTEs	buffer for filename
112h	128 BYTEs	buffer for filename
192h	21 BYTEs	findfirst/findnext search data block (see 21/4Eh)
1A7h	32 BYTEs	directory entry for found file
1C7h	81 BYTEs	copy of current directory structure for drive being accessed
218h	11 BYTEs	FCB-format filename for device name comparison
223h	*BYTE*	*apparently unused*
224h	11 BYTEs	wildcard destination specification for rename (FCB format)
22Fh	*2 BYTEs*	*unknown*
231h	*WORD*	*unknown*
233h	*5 BYTEs*	*unknown*
238h	BYTE	extended FCB file attribute (used for search attribute)
239h	BYTE	type of FCB (00h=regular, FFh=extended)
23Ah	BYTE	directory search attributes
23Bh	*BYTE*	*file open mode*
23Ch	*BYTE*	*unknown flags, bits 0 and 4*
23Dh	*BYTE*	*unknown flag or counter*
23Eh	*BYTE*	*unknown flag*
23Fh	BYTE	flag indicating how DOS function was invoked (00h=direct, INT 20h, INT 21h/FFh=server call, INT 21/AX=5D00h)
240h	*BYTE*	*unknown*
241h	*BYTE*	*unknown flag*
242h	BYTE	flag: 00h=read, 01h=write
243h	*BYTE*	*unknown drive number*
244h	*BYTE*	*unknown*
245h	*BYTE*	*unknown flag or counter*
246h	BYTE	last call 21/0Ah insert mode flag (nonzero=overwrite)
247h	BYTE	canonicalized filename referred to existing file (for 21/6Ch)
248h	*BYTE*	*unknown flag or counter*
249h	BYTE	type of process termination (00h-03h) (see 21/4Dh)
24Ah	*BYTE*	*unknown flag*
24Bh	BYTE	value with which to replace first byte of deleted file's name (normally E5h, but 00h as described under 21/13h)
24Ch	DWORD	pointer to Drive Parameter Block for critical error invocation
250h	DWORD	pointer to stack frame containing user registers on INT 21h
254h	WORD	stores SP across INT 24h

	DWORD	*pointer to DOS Drive Parameter Block for unknown int*
	WORD	*unknown*
	dWORD	*unknown temporary*
	WORD	*unknown flag; only low byte referenced*
	dWORD	*unknown temporary*
2	BYTE	Media ID byte returned by *21 1Bh, 21 1Ch*
	BYTE	apparently not referenced by kernel
	DWORD	pointer to device header
	DWORD	pointer to current SFT
	DWORD	pointer to current directory structure for drive being accessed
	DWORD	pointer to caller's PCB
4	WORD	[illegible] pointer to SFT
	WORD	temporary storage for file handle
	WORD	[illegible] see INT 21 AH=26h
	WORD	offset in DOS DS of first filename argument
	WORD	offset in DOS DS of second filename argument
2800	WORD	offset of last component in pathname or FFFFh
	dWORD	*offset of transfer address*
	dWORD	*relative cluster within file being accessed*
	WORD	*absolute cluster number being accessed*
	dWORD	*current sector number*
	dWORD	*current cluster number*
	dWORD	*current offset in file DIV bytes per sector*
	2 BYTEs	*unknown*
	dWORD	[illegible] offset in file MOD bytes per sector
	DWORD	[illegible] offset in file
	dWORD	[illegible]
	dWORD	*unknown*
	dWORD	[illegible]
	dWORD	*unknown*
	dWORD	*unknown*
	WORD	
	DWORD	number of bytes appended to file
	DWORD	*pointer to unknown disk buffer*
	DWORD	pointer to working SFT
	WORD	used by INT 21h dispatcher to store caller's BX
	WORD	used by INT 21h dispatcher to store caller's DS
	WORD	[illegible]
	DWORD	pointer to previous call frame (offset 2500h if INT 21h not currently also switched to for duration of INT 24h
	21 BYTEs	[illegible] see 21 4Eh
	32 BYTEs	directory entry for file being renamed
	331 BYTEs	critical error stack
	3[illegible] BYTEs	scratch SFT
4[illegible]	384 BYTEs	[illegible] INT 25h INT 26h
[illegible]	384 BYTEs	character I/O stack (functions 01h through 0Ch)

—DOS 3.2,3.3 only—

[illegible]	BYTE	device driver lookahead flag (see 21 64h)
[illegible]	*BYTE*	*apparently a drive number*
[illegible]	BYTE	*unknown flag*
[illegible]	*BYTE*	*unknown*

Note: For the DOS 4 + SHARE, see 21 5D0Bh; for the DOS 5+ SHARE, see 21 5D0Bh for the structure

INT 21h Function 5D07h — DOS 3.1+ network
GET REDIRECTED PRINTER MODE

Determines whether redirected printer output is treated as one continuous stream or as multiple print jobs

Call With
AX 5D07h

Returns
DL mode
00h redirected output is combined
01h redirected output in separate print jobs

Note: Undocumented, 5D07 corrupts the stack and returns the supplied AX on top of the stack
See Also: 21 5D08h, 21 5D09h, 2F 1123h

INT 21h Function 5D08h — DOS 3.1+ network
SET REDIRECTED PRINTER MODE

Specifies whether redirected output should be combined or separated into print jobs

Call With
AX 5D08h
DL mode
00h redirected output is combined
01h redirected output in separate print jobs

Notes: Called by COMMAND.COM
Undocumented, 5D08 corrupts the stack and returns the supplied AX on top of the stack
See Also: 21 5D07h, 21 5D09h, 2F 1123h

INT 21h Function 5D09h — DOS 3.1+ network
FLUSH REDIRECTED PRINTER OUTPUT

Forces redirected printer output to be printed
Call With
AX 5D09h
Notes: same as previous entry
See Also: 21 5D07h, 21 5D08h, 2F 1123h

INT 21h Function 5D0Ah — DOS 3.1+
SET EXTENDED ERROR INFORMATION

Sets the information returned by the Get Extended Error function

Call With
AX 5D0Ah
DS:DX pointer to 11-word DOS parameter block, see 5D0Bh

Returns
Nothing; next call to 21 59h will return the values in AX, BX, CX, DX, DI, and ES in corresponding registers

Note: Undocumented, 5D0A corrupts the stack on DOS 3.1 and 3.2, and on DOS 4+ in compatibility mode if the

3.1. The MS-DOS 5.0 programmer's reference set also incorrectly states that the parameter list goes in DS:SI rather than in DS:DX.
See Also: 21/5F0Bh

INT 21h Function 5D0Bh — DOS 4.x only
GET DOS SWAPPABLE DATA AREAS

Returns a list of memory regions which must be swapped out and restored to allow DOS to be reentered. Used by SHARE.EXE starting with DOS 3.3 and by COMMAND.COM starting with DOS 5.0, although the 5.0 data structure is listed here because the layout is the same as in DOS 4.x.

Call With
- AX = 5D0Bh

Returns
- CF set on error
  - AX = error code (see 21/59h)
- CF clear if successful
  - DS:SI pointer to swappable data area list (see below)

Note: Calling this function to get the swappable data areas allows DOS to be reentered unless it is in a critical section as indicated by calls to 2A/80h and 2A/81h/82h.

Some versions of DOS will return the NDA form of the list, examining the byte at offset 0Ch of the DOS data segment (see INT 21h, AX=1203h). A value of 08h indicates a DOS 3.x NDA, 01h indicates DOS 4.0/6.0, and other values are an error.
See Also: 21/5D06h, 2A/80h, 2A/81h, 2A/82h

Format of DOS 4.x swappable data area list:

Offset	Size	Description
00h	WORD	count of data areas
02h	N BYTEs	"count" copies of data area record
Offset	**Size**	**Description**
00h	DWORD	address
04h	WORD	length and type bit 15 set if swap always, clear if swap in DOS bits 14-0: length in bytes

Format of DOS 4.0-6.0 swappable data area:

Offset	Size	Description
0	varies	[illegible] list of offsets which need to be patched to enabled critical section calls (see 2A/80h) [illegible] the NDA, all offsets are 0D00Ch, but this list is still present for DOS 3.x compatibility)
00h	BYTE	critical error flag
01h	BYTE	[illegible] DOS [illegible] count of active INT 21 calls
02h	BYTE	[illegible] set if a critical error occurred or FFh
03h	BYTE	locus of last error
04h	WORD	extended error code of last error
06h	BYTE	suggested action for last error
07h	BYTE	class of last error
08h	DWORD	ES:DI pointer for last error
0Ch	DWORD	current DTA
10h	WORD	current PSP
12h	WORD	stores SP across an INT 23h

14h	WORD	return code from last process termination cleared after reading with 21 4Dh e.g. by COMMAND.COM
16h	BYTE	current drive
17h	BYTE	extended break flag
18h	*2 BYTEs*	*unknown*
—remainder need only be swapped if in DOS—		
1Ah	WORD	value of AX on call to INT 21h
1Ch	WORD	PSP segment for sharing network
1Eh	WORD	network machine number for sharing network 0000h=stalker
20h	WORD	first usable memory block found when allocating memory
22h	WORD	best usable memory block found when allocating memory
24h	WORD	last usable memory block found when allocating memory
26h	WORD	memory size in paragraphs used only during initialization
28h	*WORD*	*unknown*
2Ah	*BYTE*	*unknown*
2Bh	*BYTE*	*unknown*
2Ch	*BYTE*	*unknown*
2Dh	*BYTE*	*unknown*
2Eh	*BYTE*	*unknown*
2Fh	*BYTE*	*apparently not referenced by kernel*
30h	BYTE	day of month
31h	BYTE	month
32h	WORD	year 1980
34h	WORD	number of days since 1-1-1980
36h	BYTE	day of week (0 for Sunday)
37h	*BYTE*	*unknown*
38h	*BYTE*	*unknown*
39h	*BYTE*	*unknown*
3Ah	30 BYTEs	device driver request header see 21 0802h
58h	DWORD	pointer to device driver entry point used for calling driver
5Ch	22 BYTEs	device driver request header
72h	30 BYTEs	device driver request header
90h	*6 BYTEs*	*unknown*
96h	6 BYTEs	CLOCK$ transfer record (see 21/52h)
9Ch	*2 BYTEs*	*unknown*
9Eh	128 BYTEs	buffer for filename
11Eh	128 BYTEs	buffer for filename
19Eh	21 BYTEs	findfirst/findnext search data block (see 21/4Fh)
1B3h	32 BYTEs	directory entry for found file
1D3h	88 BYTEs	copy of current directory structure for drive being accessed
22Bh	11 BYTEs	FCB format filename for device name comparison
236h	*BYTE*	*unknown*
237h	11 BYTEs	wildcard destination specification for rename FCB format
242h	*2 BYTEs*	*unknown*
244h	*WORD*	*unknown*
246h	*5 BYTEs*	*unknown*
24Bh	BYTE	extended FCB file attributes find first search attributes
24Ch	BYTE	type of FCB (00h regular FFh extended)
24Dh	BYTE	directory search attributes
24Eh	BYTE	file open mode
24Fh	*BYTE*	*unknown flag bits*
250h	*BYTE*	*unknown flag or counter*
251h	*BYTE*	*unknown flag*

[illegible]	BYTE	[illegible] indicating how DOS function was invoked 00h = direct (INT 20h, INT 21h, FFh = far call to service call INT 21, AX=5D00h)
[illegible]	[illegible]	[illegible]
[illegible]	*BYTE*	*unknown*
	BYTE	*unknown*
	BYTE	*unknown*
	BYTE	*unknown*
[illegible]	*BYTE*	*unknown*
[illegible]	*BYTE*	*unknown*
[illegible]	[illegible]	[illegible] initialized by [illegible] to [illegible] existing file's dir at FFh
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible] process termination (00h, 03h, INT 3
[illegible]	[illegible]	[illegible]
[illegible]	*BYTE*	*unknown*
[illegible]	*BYTE*	*unknown*
60h	DWORD	[illegible] to Drive Parameter Block for critical error invocation
7Ch	DWORD	[illegible] stack frame containing user registers on INT 21h
	WORD	*stores SP*
	WORD	*DOS DS: Program Base [illegible] unknown use*
8Ch	WORD	segment of disk buffer
	WORD	*unknown*
	WORD	[illegible]
[illegible]	WORD	*unknown*
[illegible]	WORD	*unknown*
95h	BYTE	Media ID byte returned by *21 1Bh, 21 1Ch*
	BYTE	*apparently not referenced by kernel*
	DWORD	*unknown pointer*
[illegible]	DWORD	pointer to current SFT
98h	DWORD	[illegible] to current directory structure for [illegible] being accessed
9Ch	DWORD	pointer to caller's FCB
A0h	WORD	SFT [illegible] to which file being opened will refer
A2h	WORD	temporary storage for file handle
A4h	DWORD	[illegible] to [illegible] in process handle table, see INT 21 AH=26h
A8h	WORD	offset in DOS DS of first filename argument
AAh	WORD	offset in DOS DS of second filename argument
[illegible]	WORD	
[illegible]	WORD	
[illegible]	WORD	
[illegible]	WORD	[illegible]
	WORD	
[illegible]	WORD	*unknown*
[illegible]	WORD	*directory cluster number*
[illegible]	*DWORD*	*unknown*
[illegible]	*DWORD*	*unknown*
[illegible]	WORD	*unknown*
[illegible]	*DWORD*	*offset in 0h*
[illegible]	*WORD*	*unknown*
284h	WORD	bytes in partial sector
286h	WORD	number of sectors
288h	*WORD*	*unknown*
28Ah	*WORD*	*unknown*
28Ch	*WORD*	*unknown*
28Eh	DWORD	[illegible] to [illegible] file [illegible]
292h	*DWORD*	*pointer to unknown disk buffer*
296h	*DWORD*	*pointer to unknown SFT*

20Ah	WORD	used by INT 21h dispatcher to store caller's BX
20Ch	WORD	used by INT 21h dispatcher to store caller's DS
20Eh	WORD	temporary storage while saving/restoring caller's registers
2100h	DWORD	pointer to previous call frame (offset 264h) if INT 21h reentered; also switched to for duration of INT 24h
2104h	WORD	open mode/action for 21/6C00h
2106h	*BYTE*	*netbios server (00h in INT 2Fh dispatcher, 02h when a read is performed, and 03h or 05h by 21/6C00h)*
2107h	*WORD*	*apparently unused*
2109h	*DWORD*	*stored ES:DI for 21/6C00h*
210Dh	WORD	extended file open/action code; see *21/6C00h*
210Fh	WORD	extended file open attributes; see *21/6C00h*
2111h	WORD	extended file open file mode; see *21/6C00h*
2113h	DWORD	pointer to filename to open; see *21/6C00h*
2117h	*WORD*	*unknown*
2119h	*WORD*	*unknown*
211Bh	*BYTE*	*unknown*
211Ch	WORD	stores DS during call to List of Lists + 37h
211Eh	*WORD*	*unknown*
2120h	*BYTE*	*unknown*
2121h	*WORD*	*unknown but flags*
2123h	DWORD	pointer to user-supplied filename
2127h	*DWORD*	*unknown pointer*
212Bh	WORD	stores SS during call to List of Lists + 37h
212Dh	WORD	stores SP during call to List of Lists + 37h
212Fh	BYTE	flag: current stack switched to during List of Lists + 37h
3008h	21 BYTEs	FindFirst search data for source/dest of a rename operation; see 21/11h
3015h	32 BYTEs	directory entry for file being renamed
335Ah	331 BYTEs	critical error stack
4808h	384 BYTEs	list of DOS functions greater than 0Ch + INT 25h, INT 26h
6008h	384 BYTEs	character translation tables for functions 01h through 0Ch
7808h	BYTE	device driver lookahead flag; see 21/64h
7811h	*BYTE*	*apparently a drive number*
7812h	*BYTE*	*unknown flag*
7813h	*BYTE*	*unknown*
7814h	*WORD*	*unknown*
7816h	*WORD*	*unknown*
7818h	*WORD*	*unknown*
781Ah	*WORD*	*unknown*

INT 21h Function 5E01h — DOS 3.1+ network
SET MACHINE NAME

Specify the system's network machine name and number

Call With:

AX	5E01h
CH	00h undefine name (make it invalid)
	else define name
CL	name number
DS:DX	pointer to 15-character blank-padded ASCIZ name

See Also: *21/5E00h*

INT 21h Function 5E04h — DOS 3.1+ network
SET PRINTER MODE

Sp[illegible] s[illegible] [illegible]

Call With:
AX 5E04h
redirection list index see *21 5F02*
DX
set 0 set if binary clear if text (tabs expanded to blanks
Returns:
CF set on error
AX error code see *21 59*
CF clear if successful
Note: [illegible] 5E04h [illegible] see *21 5F02* 5E05h [illegible] end to 21 111Eh with AX pushed on stack
See Also: 21 5E05h, 21 111Eh

INT 21h Function 5E05h — DOS 3.1+ network
GET PRINTER MODE

[illegible]

Call With:
AX 5E05h
redirection list index see *21 5F02h*
Returns:
CF set on error
AX error code see *21 59*
CF clear if successful
DX printer mode see 21 5E04h
Note: This func[illegible] calls 21 111Eh with 5E05h [illegible] on the stack
See Also: 21 5E04h, 21 111Eh

INT 21h Function 5F00h — DOS 3.1+ network
GET REDIRECTION MODE

Determine whether disk or printer redirection is currently enabled

Call With:
[illegible]
BL redirection type 03h printer 04h disk drive
Returns:
CF
[illegible]
CF clear if successful
BH redirection state 00h off 01h on
Note: [illegible] AX [illegible] on the stack
See Also: 21 5F01h, 21 111Eh

INT 21h Function 5F01h — DOS 3.1+ Network
SET REDIRECTION MODE

Specify whether disk or printer redirection is enabled

Call With
AX 5F01h
BL redirection type: 03h printer, 04h disk drive
BH redirection state: 00h off, 01h on
Returns:
CF set on error
AX error code (see *21,59h*)
CF clear if successful
Note: When redirection is off, the local device (if any) rather than the remote device is used. This function merely calls 21,1111h with AX on top of the stack.
See Also: 21,5F00h, 21,1111h

INT 21h Function 5F05h — DOS 4.x + Microsoft Networks
GET REDIRECTION LIST EXTENDED ENTRY

Return the source and target of a given redirection, as well as its status and type.

Call With
AX 5F05h
BX redirection list index
DS:SI pointer to buffer for ASCIZ source device name
ES:DI pointer to buffer for destination ASCIZ network path
Returns:
CF set on error
AX error code (see *21,59h*)
CF clear if successful
BH device status flag: bit 0 clear if valid
BL device type: 03h if printer, 04h if drive
CX stored parameter value (user data)
BP NETBIOS local session number
DS:SI buffer filled
ES:DI buffer filled
Notes: If local session number is 00h, it does not mean that the redirection's session number is 00h. However, if a session number is assigned by NETBIOS, INT 2Ah/AH=5Dh/AL=01h can be used to determine whether the connection is still valid.
This function merely calls 21,1111h with AX on top of the stack.
See Also: 21,5F06h, 21,1111h

INT 21h Function 5F06h — Network
GET REDIRECTION LIST

This function appears to be a more general version of *21,5F02h* (get redirection list) and 21,5F05h (get redirection list extended entry).

Call With
AX 5F06h
additional arguments, if any: unknown
Returns:
unknown
Note: This function merely calls 21,1111h with AX on top of the stack.
See Also: 21,5F00h, 21,1111h

INT 21h Function 5F07h — DOS 5+
ENABLE DRIVE

[illegible] was previously temporarily disabled by setting the "valid" bit in the drive's Current Directory Structure

Call With
AX 5F07h
DL [illegible] 0=A
Returns
CF clear if successful
CF set on error
AX error code (01h) see 21/59
See Also: 21/52h, 21/5408h

INT 21h Function 5F08h — DOS 5+
DISABLE DRIVE

[illegible] a drive by clearing the "valid" bit in the drive's Current Directory Structure. For an alternate approach, see DRIVNET.C in Chapter 8

Call With
AX 5F08h
DL drive number (0=A)
Returns
CF clear if successful
CF set on error
AX error code (01h) see 21/59
See Also: 21/52h, 21/5407h

INT 21h Functions 5F32h-5F55h — LAN Manager
NAMED PIPES FUNCTIONS

Microsoft LAN Manager uses 21/5F for named Named Pipes and other services. Some of these calls are [illegible] by the Novell DOS Named Pipe Extender. Banyan VINES and the OS/2 DOS box

5F32h DosQNmPipeInfo
5F33h DosQNmPHandState
[illegible] DosSetNmPHandState
5F35h DosPeekNmPipe
[illegible] DosTransactNmPipe
[illegible] DosRawReadNmPipe
[illegible] DosRawWriteNmPipe
5F39h DosListen[illegible]NmPipe
5F3Ah DosQuery[illegible]NmPipe
5F4Fh NetWksta

These 21/5F calls are issued for example by NETAPI.DLL in Windows and by Microsoft's SQL Server. In the OS/2 2.0 DOS box, DOS Net Name and the LANBRD make assistant calls to 21/5F34 DosSetNmPHandState

For more information see [illegible] Ross and Mike Shaw, "The Undocumented LAN Manager and Named Pipe APIs for DOS and Windows," *Dr. Dobb's Journal*, April 1993

INT 21h Function 60h — DOS 3.0+
CANONICALIZE FILENAME OR PATH (TRUENAME)

Given a pointer to a string containing a pathname, this function returns a pointer to a string containing the absolute pathname which takes into account all drive letters assigned by JOIN, SUBST, ASSIGN, or network redirections. This function corresponds to the undocumented TRUENAME command in COMMAND.COM.

Call With
- AH = 60h
- DS:SI = pointer to ASCIZ filename or path
- ES:DI = pointer to 128-byte buffer for canonicalized name

Returns
- CF set on error
  - AX = error code
    - 02h invalid component in directory path or drive letter only
    - 03h malformed path or invalid drive letter
  - ES:DI buffer unchanged
- CF clear if successful
  - AH = 00h
  - AL = destroyed (00h or 5Ch or last char of current dir on drive)
  - ES:DI = pointer to uppercased canonicalized name of form D:\PATH\FILE.EXT or \\MACHINE\PATH\FILE.EXT

Notes: The input path need not actually exist.

Forward slashes are converted to backslashes, and ".." and "." in the path are resolved.

Uppercasing and backslash conversion start with the first component that does not contain wildcards.

If the path specifies a JOINed drive, the actual pathname is returned, not the drive letter used to JOIN the directory. Similarly, for SUBSTed, ASSIGNed, or network redirected drives. Because of this, it is possible to get a path longer than the original input string. See also INT 2Fh AX=1223h, JOINs, ASSIGNs, and network redirections.

Under MS-DOS 3.3 through 6.00, the case of the translated drive letter may not match the case of the drive letter in the input string. For example, if "A:" is JOINed to "C:\DOS", then "a:\dos" may be returned instead of "A:\DOS". In these cases, the returned string consists of the JOINed drive letter and colon appended to the string "\DOS", instead of just changing the drive letter. This also occurs in other cases where "A:" would be valid for the explicit drive letter.

This function is supported by the DOS 3.1+ redirector.

NetWare 2.x redirector supports canonicalization with the exception of NetWare 386 support for extended characters (code page 437 letters). NetWare 3.0 through 3.11 and 4.0 support "A:" but not "A:\", one should use "A:\." instead.

For DOS 3.x to 6.00, the case of the drive letter may not be the same as the case specified in the input string. Under DOS 3.3 and 4.0, the special output buffer is not zero-terminated.

See Also: INT 2Fh AX=1221h

INT 21h Function 61h — DOS 3+
UNUSED

This function performs no action and returns immediately.

INT 21h Function 6300h — DOS 2.25
GET DOUBLE BYTE CHARACTER SET LEAD BYTE TABLE

[illegible] this function specifies the ranges of characters which are the first half of a double byte character

Call With
AX 6300h
Returns
CF clear if successful
DS:SI pointer to lead byte table (see below for format)
all other registers except CS, IP and SS:SP destroyed
CF set on error
AX error code (01h) (see *21,59h*)
Notes: [illegible] SS:SP [illegible] MS DOS 3.30 treats this as [illegible] AX=0800h [illegible] Microsoft Far East Windows SDK refers to "DBCS MS DOS 2.21."
See Also: *21,67h, 21,6800h, 21,6801h, 21,6301h*

Format of lead byte table entry:

Offset	Size	Description
00	2 BYTEs	[illegible] start of [illegible] double byte chars
02h	2 BYTEs	[illegible] end of [illegible] double byte chars
N	2 BYTEs	00h,00h end flag

INT 21h Function 6300h — Far East DOS 3.2+
GET DOUBLE BYTE CHARACTER SET LEAD BYTE TABLE

DS:SI [illegible] specifies the ranges of characters which are the first half of a double byte character

Call With
AX 6300h
Returns
AL status
00h successful
DS:SI pointer to DBCS table (see below)
all other registers except CS, IP and SS:SP destroyed
FFh not supported
Notes: the US version of MS DOS 3.30 treats this as an unused function, setting AL=00h and returning immediately; the US version of DOS 4.0+ accepts this function but returns an empty list
See Also: 21,6301h, 21,65

Format of DBCS table

Offset	Size	Description
00h	2 BYTEs	[illegible] start of [illegible] double byte chars
02h	2 BYTEs	[illegible] end of [illegible] double byte chars
N	2 BYTEs	00h,00h end flag

INT 21h Function 6301h — DOS 2.25, Far East DOS 3.2+
SET KOREAN (HANGEUL) INPUT MODE

Specific version for DOS ... [illegible] ... may return partially formed double-byte characters. This function sets the "interim console flag."

Call With
- AX 6301h
- DL new mode
  - [illegible] characters to DOS to [illegible]
  - 01h return partially formed interim characters also

Returns
- AL status
  - 00h successful
  - FFh invalid mode

Note: see the Microsoft Windows Far East SDK
See Also: [illegible] 6300h, 21 6302h

INT 21h Function 6302h — DOS 2.25, Far East DOS 3.2+
GET KOREAN (HANGEUL) INPUT MODE

Determine whether DOS ... [illegible] ... partially formed double-byte characters

Call With
- AX 6302h

Returns
- AL status
  - 00h successful
    - DL current input mode
      - [illegible] characters clears interim
      - [illegible] interim console flag
  - FFh not supported

See Also: *21 07h, 21 08h, 21 0Bh*, 21 6300h, 21 6301h

INT 21h Function 64h — DOS 3.2+
SET DEVICE DRIVER LOOKAHEAD FLAG

Specifies whether DOS ... [illegible] ... device driver for input

Call With
- AH 64h
- AL flag
  - 00h [illegible] before 21 01h 08h 0Ah
  - nonzero don't call driver function 5

Returns
- nothing

Notes: This function is called by DOS 3.3+ PRINT.COM
- [illegible] DOS ... [illegible] during another INT 21h call

See Also: *21 0Bh, 21 0Ch, 21 0Ah*, 21 5D00h

INT 21h Function 64h — OS/2 2.x Virtual DOS Machine
GET/SET TASK TITLE

[illegible] window of an OS/2 2.x virtual DOS machine (VDM)

Call With

AH 64h
BX 0000h
CX 636Ch
DX function
0000h enable automatic title switch on 21/4Bh
0001h set session title
ES:DI pointer to new ASCIZ title or [illegible] to restore original title
0002h get session title
ES:DI pointer to buffer for current title

Returns

buffer filled (note: 00h if title never changed)

See Also: 21/4B

Notes: [illegible] DOS programs running in a VDM [illegible] OS/2 Dos2Set Session Title and of OS/2 [illegible] Dos32Post [illegible]

INT 21h Function 6505h — DOS 3.3+
GET FILENAME TERMINATOR TABLE

Return information about the characters which terminate [illegible]

Call With

AH 65h
AL info ID
05h get pointer to filename terminator table
BX code page (-1 = global code page)
DX country ID (-1 = current country)
ES:DI pointer to country information buffer (see below)
CX size of buffer (>= 5)

Returns

CF set on error
AX error code (see 21/59h)
CF clear if successful
CX size of country information [illegible]
ES:DI pointer to country information

Notes: [illegible] has been documented for DOS 5.0, but was undocumented in earlier versions.
NLSFUNC must be installed to get information for countries other than the default country.

See Also: 21/38h, 2F/1401h, 2F/1402h

Format of country information

Offset	Size	Description
00h	BYTE	info ID
01h	DWORD	[illegible] see below

Format of filename terminator table:

Offset	Size	Description
00h	WORD	table size (not counting this word)
02h	*BYTE*	*unknown (01h for MS DOS 3.30 & 4.00)*
03h	BYTE	lowest permissible character value for filename
04h	BYTE	highest permissible character value for filename
05h	*BYTE*	*unknown (00h for MS DOS 3.30 & 4.00)*
06h	BYTE	first excluded character value (range | of characters is illegal)
07h	BYTE	last excluded character value (range | of characters is illegal)
08h	*BYTE*	*unknown (02h for MS DOS 3.30 & 4.00)*
09h	BYTE	number of illegal terminator characters
0Ah	N BYTEs	characters which terminate a filename

Note: Partially documented for DOS 3.0, but undocumented for earlier versions

INT 21h Functions 6520h to 6522h — DOS 4+
COUNTRY DEPENDENT CHARACTER CAPITALIZATION

Capitalize a character or string using the capitalization rules for the current country

Call With
- AH 65h
- AL function
  - 20h capitalize character
    - DL character to capitalize
    - **Returns:**
      - DL capitalized character
  - 21h capitalize string
    - DS:DX pointer to string to capitalize
    - CX length of string
  - 22h capitalize ASCIZ string
    - DS:DX pointer to ASCIZ string to capitalize

Returns
- CF set on error
  - AX error code (see *21,59h*)
- CF clear if successful

Note: Undocumented function for DOS 3.30 & 4.00, but documented for DOS 4.x

INT 21h Function 6523h — DOS 4+
Determine If Character Represents Yes/no Response

Compare the specified character against the YES and NO responses for the current country

Call With
- AX 6523h
- DL character
- DH second character of double-byte character if applicable

Returns:
- CF set on error
- CF clear if successful
  - AX type
    - 00h no
    - 01h yes
    - 02h neither yes nor no

INT 21h Functions 65A0h to 65A2h — DOS 4+
Country dependent Filename Capitalization

[illegible] the current country

Call With
AH 65h
AL [illegible] function
A0h capitalize filename character
[illegible]
Returns
[illegible] capitalized character
A1h capitalize counted filename string
DS:DX pointer to filename [illegible]
CX length of string
A2h capitalize ASCIIZ filename
DS:DX pointer to ASCIIZ filename to capitalize
Returns
CF set on error
AX error code (see 21-59h)
CF clear if successful
Notes [illegible] DOS 3.30 [illegible] code sets a pointer [illegible]

INT 21h Function 67h — DOS 3.3+
SET HANDLE COUNT

[illegible] This function is [illegible]

Call With
AH 67h
BX size of new file handle table for process
Returns
CF clear if successful
CF set on error
AX error code (see 21-59h)
Notes [illegible] released and the [illegible] 20 handles

For file handle tables [illegible] 20 handles DOS [illegible] handle number. Subsequent file handle [illegible] a new block is allocated and the system

Only the first 20 handles are copied to child processes in DOS 3.3 to 6.0

Interrupt [illegible] a high level language. See Compiler

BUGS [illegible] Generates a fatal error if [illegible] requests for an even number of handles

See Also: 21-26h

INT 21h Function 69h — DOS 4.0+
GET/SET DISK SERIAL NUMBER

Determine or specify a disk's serial number and volume label

Call With
AH 69h
AL subfunction
00h get serial number
01h set serial number
BL drive (0=default, 1=A, 2=B, etc)
DS:DX pointer to disk info (see below)
Returns:
CF set on error
AX error code (see *21,59h*)
CF clear if successful
AX destroyed
(AL=00h) buffer filled with appropriate values from extended BPB
(AL=01h) extended BPB on disk set to values from buffer
Notes: (Novell) does not check to see that the drive letter is valid; errors are returned in AX
Error 0Dh if set serial if drive is not extended BPB capable disk
This call does not work on network drives (error 0001h)
After the first two bytes, the buffer is exactly the same as bytes 27 through 3Dh of the extended BPB on the disk
This function is supported under Novell NetWare versions 2.0A through 3.11, but returned serial number is zero and DIR will not display the volume label in a NetWare volume directory, and the file system is set to "FAT16"
The volume label which is read or set by this function is the one stored in the extended BPB on disks for which DOS 4.0+ rather than the special root directory entry used by the DIR command (see COMMAND.COM,2+). Under DOS 4.0+, the label is stored in both places
See Also: 21,440Dh/CX=0866h Get Media ID

Format of disk info:

Offset	Size	Description
00h	WORD	(block device)
02h	DWORD	disk serial number (binary)
06h	11 BYTEs	volume label or "NO NAME" if none present
11h	8 BYTEs	(FAT) "FAT12" or "FAT16"

INT 21h Function 6Ah — DOS 4+
COMMIT FILE

This call is identical to undocumented function 68h in DOS 3.0 and 3.01, but it is not known whether the two functions are identical in DOS 4.x

Call With
AH 6Ah
BX file handle
Returns
CF clear if successful
AH 68h
CF set on error
AX error code
See Also: *21,68h*

INT 21h Function 6Bh — DOS 4.x only
UNKNOWN FUNCTION

The purpose of this function is not known, but it appears to be related to network labeled file systems

Call With
AH 68h
AL subfunction
subfunction 41h
DS:SI pointer to Current Directory Structure
CL drive (1=A)
subfunction 42h
DS:SI pointer to unknown item
CL *file handle*
subfunction 47h
DS:SI pointer to Current Directory
DL unknown
CX drive (0=A)
Returns
CF set on error
AX error code (see *21,59h*)
CF cleared if successful
Note This call is passed through to INT 21 112Fh with AX on top of the stack
See Also: 21,112Fh

INT 21h Function 68h — DOS 5+
NULL FUNCTION

This function performs no action and returns to the caller.

INT 21h Functions 6Dh 6Fh — MS DOS 5+ in ROM, OS/2
DOS IN ROM FUNCTIONS

Microsoft's ROM-DOS and IBM's ROS-OS use INT 21 6Dh through 21 6Fh for a set of functions that are known as the IBM DOS Command Interface (CI).

6D00h Find First ROM Program
6Eh Find Next ROM Program
6F00h Get ROM Scan Start Address
6F01h Set ROM Scan Start Address
6F02h Get Exclusion Region List
6F03h Set Exclusion Region List

For more information, see the interrupt list on disk and Chappell's *DOS Internals*. To detect DOS in ROM, use documented 21,3306
[illegible] DOS, programs access to the DosMkDir2
[illegible] see chapter 4 and the [illegible] list on disk.

INT 21h Functions 71h 72h — Chicago
CHICAGO LONG FILENAME FUNCTIONS

[illegible] DOS, Windows, 21 [illegible] provide DOS programs with access to [illegible]. A DOS program will be able to [illegible] 21,7[illegible] AX to determine whether the subfunction [illegible] DOS. [illegible] because the old DOS Get Current Directory function [illegible] 21,47h which returns only the pathname as 21,7147h while the other registers and [illegible] pointed to by DS:SI must be large enough to [illegible] pathname. [illegible] the Chicago 21,4303 Get Volume Information function to get the length of the [illegible] path.

The following are the documented INT 21h long filename functions, with their Win32 API equivalents

7139h	CreateDirectory
713Ah	RemoveDirectory
713Bh	SetCurrentDirectory
7141h	DeleteFile
7143h	INT 21h GetFileAttributes
7143h	INT 21h SetFileAttributes
714Eh	GetCurrentDirectory
714Fh	FindFirstFile
714Fh	FindNextFile
7156h	MoveFile
716Ch	CreateFile and OpenFile

If the 21 71XX function is not supported (AX = 7100h and sets the carry flag), then for example because the volume does not support long filenames, DOS 7 will automatically call the old 21 XX function 1 (for example 21 714E is called as 21 4E) (AX = 7100h on INT 21 4)

INT 21 71A0 (long filename version of 21 60) is also documented to be provided

Although new DOS 7 uses 21 2 and 21 3B, Microsoft recommends use of DOS support only for all but 21 71A0 (GetFullPathName) and 21 71A6 (GetFileInformationByHandle), which are still required because the Win32 API supports multiple simultaneous file handles (which must be passed to FindNext 2 71A1 and which must be used to close with FindClose)

For more information see chapter 8 and eventually Microsoft's documentation on Chicago

INT 21h Function 80h — European MS-DOS 4.0

AEXEC - EXECUTE PROGRAM IN BACKGROUND

Asynchronously execute a program, creating a new process for it. Although DOS 4 does not document the known functions on the next several pages are in fact present. Newly documented functions are marked here as such. For knowledge there are a couple of functions which are new to European MS-DOS 4.0 as a OEM version with the Asian support which is left out in the United number of systems between the mainstream versions 3.2 and 5. Some functions of Windows 3 DOS 2 including the New Executable (NE) file format first appeared in European MS-DOS 4.0. See 21 87 for the European MS-DOS install check

Call With
- AH 80h
- CX mode
  - 0000h place child in zombie mode to exit to preserve exit code
  - 0001h discard child process and exit code on termination
- DS:DX pointer to ASCIZ full program name
- ES:BX pointer to parameter block as for 21 4B04h

Returns
- CF clear if successful
  - AX Command Subgroup ID (CSID)
- CF set on error
  - AX error code (see *21 59h*)

Notes DOS 3.x functions called by the DETACH command

There is a system-wide limit of 32 processes

See 21 87h for a possible installation check
See Also 21 1804h 21 87h 21 14000h"2DPC P"

INT 21h Function 81h — European MS-DOS 4.0
"FREEZE" STOP A PROCESS

See INT 21h function 80h for general comments on European MS DOS 4.0

Call With
AH 81h
CX Process ID of head of command subtree
Returns
CF clear if successful
CF set on error
AX error code no such process
See Also: AH 82h AH 89h AX 8100h

INT 21h Function 82h — European MS DOS 4.0
"RESUME" RESTART A PROCESS

See INT 21h function 80h for general comments on European MS DOS 4.0

Call With
AH 82h
BX flag 00h resume command subtree 01h only specified process
CX Process ID of head of command subtree
Returns
CF clear if successful
CF set on error
AX error code no such process
See Also: 21 81h

INT 21h Function 83h — European MS-DOS 4.0
"PARTITION" GET/SET FOREGROUND PARTITION SIZE

Call With
AH 83h

AL function
09h get size
01h set new size
BX new size in paragraphs

Returns
CF clear if successful
BX current size (function 00h) or old size (function 01h)
CF set on error
AX error code (01h 07h 08h) see RBL 59E

Notes: If the partition size is set to 0000h, no partition management is done and all memory allocations is compatible with DOS 3.2

The partition size can be changed regardless of what use is being made of the chain of memory blocks subsequent allocations will follow the partition rules (only one of all processes may allocate out of the ground memory, background processes allocate background memory from their foreground process only)

See Also: *INT 21 Function 48h* 21 4Ah

INT 21h Function 8400h — European MS-DOS 4.0
"CREATMEM" CREATE A SHARED MEMORY AREA

Create an area of memory which may be accessed by multiple processes See INT 21h Function 8001h for general memory allocation in European MS-DOS 4.0

Call With
AX 8400h
BX size in bytes (0000h = 65536)
CX flags
bit 0 zero initialize segment
DS:DX pointer to ASCIZ name (must begin with "\SHAREMEM\")

Returns
CF clear if successful
AX segment address of shared memory block (not PSP)
CF set on error
AX error code (06h 8Ah) see *INT 21 Functions 59h and INT 21h Function 4Dh*

Notes: Shared memory objects are created in special files thus the restriction on the names
On successful creation the reference count is set to 1

See Also: 21 8401h 21 8402h

INT 21h Function 8401h — European MS-DOS 4.0
"GETMEM" OBTAIN ACCESS TO SHARED MEMORY AREA

Get address of a previously created area of memory which may be accessed by multiple processes

Call With
AX 8401h
CX flags
bit 0 initialize segment ignored in MS-DOS 4.0
DS:DX pointer to ASCIZ name (must begin with "\SHAREMEM\")

Returns
CF clear if successful
AX segment address of shared memory global object
CX size in bytes
CF set on error
AX error code (invalid name)

Note: This call increments the reference count for the shared memory area
See Also: AX=8400h, AX=8402h

INT 21h Function 8402h — European MS-DOS 4.0
"RELEASEMEM" — FREE SHARED MEMORY AREA

[illegible] shared memory will no longer be used with the caller

Call With:
AX = 8402h
BX = handle (segment address of shared memory area)
Returns:
CF = 0 if successful
CF = 1 if error
AX = error code (no such name)
Note: [illegible]
See Also: AX=8400h, AX=8401

INT 21h Function 86h — European MS-DOS 4.0
SETFILETABLE — INSTALL NEW FILE HANDLE TABLE

[illegible] handle table, which can be a subset of bytes the caller can open simultaneously
Call With:
AH = 86h
BX = total number of file handles in new table
Returns:
CF = 0 if successful
CF = 1 if error
AX = error code (06h,08h) — see AH=59h
Notes: All currently open files are copied to the new table
[illegible] 21 functions, except 21 AH=3Eh, are duplicated by child
[illegible]
closing current open tables
See Also: 21 AH=26h, 21 AH=67h

INT 21h Function 87h — European MS-DOS 4.0
"GETPID" — GET PROCESS IDENTIFIER

[illegible] process. This call can also be used as a quick install check for European MS-DOS 4.0
Call With:
AH = 87h
Returns:
AX = Process ID (PID)
BX = parent process's PID
CX = Command Subgroup ID (CSID)
Notes: [illegible]
[illegible] 21 AH=00h, etc.
[illegible] European MS-DOS [illegible] set AH=00h and check whether AH is nonzero on return
See Also: 21 AH=30h, *21 AH=62h, 21 AH=80h*

INT 21h Function 89h — European MS-DOS 4.0
SLEEP

Suspend the calling process for the specified duration

Call With
- AH 89h
- CX time in milliseconds or 0000h to give up time slice

Returns
- CF clear if successful
  - CX 0000h
- CF set on error
  - AX error code (interrupted system call)
  - CX sleep time remaining

Notes: The sleep interval is rounded up to the next higher increment of the scheduler clock and may be extended further if other processes are running

This call may be interrupted by signals (see 21,4Dh)

The maximum interval is the same as the Microsoft C 4.0 routine clock

Background processes (those with lower priority than the foreground process) and shell 1 busy periodically steal the CPU

See Also: 21,81h, *INT 15,AX=1000h*, *21,1680h*

INT 21h Function 8Ah — European MS-DOS 4.0
"CWAIT" WAIT FOR CHILD TO TERMINATE

Get return code of terminated child process, optionally suspend calling program until child terminates. See INT 21h Function 4Ch for program termination codes. Undocumented in MS-DOS 4.0

Call With
- AH 8Ah
- BL range: 00h command subtree, 01h any child
- BH suspend flag
  - 00h suspend if children exist but none are dead
  - 01h return if no dead children
- CX Process ID of head of command subtree

Returns
- CF clear if successful
  - AH termination type
    - 00h normal termination
    - 01h aborted by Control-C
    - 02h aborted by I/O error
    - 03h terminate and stay resident
    - 04h aborted by signal
    - 05h aborted by program error
  - AL return code from child or aborting signal
  - BX PID of child, 0000h if no dead children
- CF set on error
  - AX error code (no child,interrupted system call)

See Also: 21,4B04h, *21,4D00*, *21,80h*, *21,81h*

INT 21h Function 8Ch — European MS-DOS 4.0
SET SIGNAL HANDLER

Set the routine to be called on a number of exceptional conditions

Call With
AH 8Ch
AL signal number (see below)
BL action (see below)
DS:DX pointer to signal handler (see below)
Returns
CF clear if successful
AL previous action
ES:BX pointer to previous signal handler
CF set on error
AX error code (01h invalid SigNumber or Action) (see *AH=59h*)
Note: Will also send to the most recently installed handler
See Also: 21/8Dh

Values for signal number:

01	SIG^C^P	Ctrl-C or Ctrl-P user-defined interrupt key
08h	SIGTERM	program termination
09h	SIGPIPE	broken pipe
0Dh	SIGUSR1	reserved for user definition
0Fh	SIGUSR2	reserved for user definition

Values for signal action:

00h	SIG_DFL	terminate process on receipt
01h	SIG_IGN	ignore signal
02h	SIG_GET	signal is accepted
03h	SIG_ERR	sender gets error
04h	SIG_ACK	acknowledge receipt of signal, but do not change current setting

Signal handler is called with:
AL signal number
AH signal argument
Returns
BL=FFh, CF set: terminate process
BL=00h, CF clear, ZF set: signal was sent to local process and dealt with as error
BL=00h, CF clear, ZF clear: signal was sent to other process successfully
BL=01h: signal was sent to local process successfully
Note: Default handler may not perform correct actions if DOS 3.0+ by resetting the stack pointer and jumping to the address of the handler. The handler can ignore the signal by calling this function with BL=04h.

INT 21h Function 8Dh — European MS-DOS 4.0

SEND SIGNAL

Invoke the exceptional condition handler for the specified process

Call With
AH 8Dh
AL signal number (see AH=8Ch)
BH signal argument
BL action
00h send to entire command subtree
01h send only to specified process
DX Process ID
Returns
CF clear if successful
CF set on error

AX error code (01h,00h) see AH=59h

Note: Error 00h may be returned if one or more of the affected processes have an error handler for the signal

See Also: 21 8C h

INT 21h Function 8E00h — European MS-DOS 4.0
"SETPRI" GET/SET PROCESS PRIORITY

Specify or determine the execution priority of the specified process or the process and all of its children

Call With
- AX 8E00h
- BH 00h
- BL action
  - 00h set priority for command subtree
  - 01h set priority for specified process only
- CX Process ID
- DH 00h
- DL change in priority (00h to get priority)

Returns
- CF clear if successful
  - DL process priority
  - DH destroyed
- CF set on error
  - AX error code (01h,no such process) see *21 59h*

See Also: 2 8C h

INT 21h Function 93h — European MS DOS 4.0
"PIPE" - CREATE A NEW PIPE

Create a communications channel which can be used for multiprocess data and command exchanges

Call With
- AH 93h
- CX size in bytes

Returns
- CF clear if successful
  - AX read handle
  - BX write handle
- CF set on error
  - AX error code (08h) see AH=59h

See Also: *21 3Ch, 21 3Dh*, 21 40h, 21 84h

INT 21h Function 95h — European MS-DOS 4.0
HARD ERROR PROCESSING

Specify whether hard critical errors should be automatically fail the system call or invoke an INT 24h

Call With
- AH 95h
- AL new state
  - 00h enabled
  - 01h disabled, automatically fail hard errors

Returns
AX previous setting
See Also: *INT 24h*

INT 21h Function 99h — European MS-DOS 4.0
PBLOCK" - BLOCK A PROCESS

Suspend execution of the current process until another process sends it a restart signal or a timeout occurs

Call With
AH 99h
DS:BX pointer to memory location on which to block
CX timeout in milliseconds
DH nonzero if uninterruptible
Returns
CF clear if awakened by event
AX 0000h
CF set if unusual wakeup
ZF set if timeout, clear if interrupted by signal
AX nonzero
See Also: 21 9Ah, 21 0802h

INT 21h Function 9Ah — European MS-DOS 4.0
PRUN' - UNBLOCK A PROCESS

Restart all processes waiting for the specified "restart" signal

Call With
AH 9Ah
DS:DX pointer to memory block containing blocked processes to be unblocked
Returns
AX number of processes awakened
ZF set if no processes awakened
See Also: 21 99h, 21 0802h

INT 28h — DOS 2+
DOS IDLE INTERRUPT

Invoked when DOS is waiting for input from the keyboard, but is safe to perform any DOS function. The default handler does nothing, but it is safe to call DOS to perform any function except those which change the DOS critical flag. DOS is not reentrant during such input functions, but it is safe to issue INT 28h requests. DOS will invoke the foreground program's waiting for user input

Called with
SS:SP top of MS-DOS stack for I/O functions
Returns
all registers preserved
Notes: INT 28h is not issued during INT 21h functions greater than 0Ch, or 0Ch through 0Ch if the DOS critical flag must be set in order to call DOS. It is safe to issue INT 28h from within a TSR without destroying the DOS stacks.
Compare to 2Fh and 21 4Dh. Some versions of DOS 2+ hand off may not use a handle which refers to the CON device

When [illegible] DOS [illegible] truly busy and should not be reentered

The default handler is an IRET instruction

[illegible]

[illegible] superseded by 21 1680

See Also: 21 34h, 2A/84h, 21 1680h

INT 29h — DOS 2+
FAST CONSOLE OUTPUT

This [illegible] attribute word has bit 4 set

Call With
AL character to display

Returns
[illegible]

Notes: [illegible] and assume that ANSI.SYS is installed at the INT 29h segment as [illegible]

The default handler under DOS 2.x and 3.x simply calls INT 10 AH=0Eh; see Figure 6.1

See Also: 21 52h, 21 0802l

INT 2Ah Function 00h — Network
INSTALLATION CHECK

Determine [illegible] Microsoft Networks [illegible] network software

Call With
AL [illegible]

Returns
AL [illegible]

See Also: [illegible]

INT 2Ah Function 01h — Network
EXECUTE NETBIOS REQUEST,NO ERROR RETRY

This [illegible] INT 5Ch in NETBIOS.EXE

Call With
AH 01h
ES:BX pointer to Network Control Block; see *INT 5Ch*

Returns
AL NetBIOS error code
AH 00h if no error
01h if error

See Also: 2A 04h, 2A 0500h, *INT 5Ch*

INT 2Ah Function 02h — Network
SET NETWORK PRINTER MODE

Sets the operating mode of the network printer

Call With
AH 02h
additional arguments if any: unknown

Returns

INT 2Ah Function 0300h — Network
CHECK DIRECT I/O

[illegible]

Call With
AX 0300

[illegible]

Returns
CF clear if direct physical addressing INT 13h INT 25h permissible
CF set Direct Access to Device

Notes
[illegible]

See Also INT 13h INT 25h INT 26h 21 xx03

INT 2Ah Function 04h — Network
EXECUTE NETBIOS REQUEST

[illegible]

Call With
AH 04
AL
Bit 0 automatically retry request on errors 02h 12h and 21h
01 no retry
pointer to Network Control Block

Returns
0000h Successful
01h error
AL error code

Note This function invokes either INT 5Bh or INT 5Ch as appropriate
See Also [illegible] 2A 0500h INT 5Bh INT 5Ch

INT 2Ah Function 0500h — Network
GET NETWORK RESOURCE AVAILABILITY

Determine the available amounts of several important network resources

Call With
AX 0500h

Returns
[illegible]
number of network control blocks available
number of networks
number of network sessions available

See Also 2A 01h 2A 04h INT 5C h

INT 2Ah Function 06h — NETBIOS, LANtastic
NETWORK PRINT-STREAM CONTROL

Specify behavior of redirected network printer output

Call With
- AH 06h
- AL 01 [illegible]
  02 [illegible]
  03h flush printer output and start new print job

Returns
- CF set on error
  - AX error code
- CF clear if successful

Notes: [illegible]
LANtastic v4.x no longer supports this call

See Also: 21 5D08h, 21 5D09h, 2F 1125h

INT 2Ah Function 2001h — MS Networks or NETBIOS
UNKNOWN FUNCTION

The purpose of this function is not known

Note: This function is intercepted by DESQview 2.x

INT 2Ah Functions 2002h and 2003h — Network
UNKNOWN FUNCTIONS

The purpose of these functions is not known

Note: These functions are called by MS DOS 3.30 & 00 MPI.SYS

INT 2Ah Function 7802h — PC LAN PROG v1.31+
GET LOGGED ON USER NAME

Call With
- AX 7802h
- ES:DI pointer to 8-byte buffer to be filled

Returns:
- AL 00h if no user logged on to Extended Services
  nonzero if user logged on to Extended Services

[illegible]

INT 2Ah Function 80h — Network
BEGIN DOS CRITICAL SECTION

[illegible] region of code is be[illegible] device drivers, to [illegible] tasking device driver

Called With
- AH 80h
- AL critical section number: 00h-0Fh
  01h DOS kernel SHARE.EXE DOSMGR
  [illegible]
  02h DOS kernel DOSMGR

05h DOS 4.x only RESUME_REDIR_PC_LAN
06h DOS 4.x only RESUME
08h ASSIGN.COM
09h ASSIGN
0Ah MSCDEX
0Bh PC LAN

Note:

risk which attempts to execute an active critical section

See CARRYSET Flag in Chapter 9
See Also: 2A 81h, 2A 82h, 2A 87h, 21 5D00h, 21 5D0Bh

INT 2Ah Function 81h — Network
END DOS CRITICAL SECTION

DOS serial and some of the DOS proc s call this function to indicate that an uninterruptible critical code has been completed

Called With:

81h
critical section number to end (0Ah-0Dh, see 2A 80h)

Notes: This function is normally hooked rather than called

Do not hook or chain to

See Also: 2A 80h, 2A 82h, 2A 83h

INT 2Ah Function 82h — Network
END DOS CRITICAL SECTIONS 0 THROUGH 7

DOS critical sections 0 which may have been left set by an aborted process or DOS

Called With:

Note:

that AH except 59h and on process termination

the critical sections 0 through 7
See Also: 2A 81h

INT 2Ah Function 84h — Network
KEYBOARD BUSY LOOP

This interrupt [illegible] to be called

Called With
AH 84h
Note: [illegible] DOS [illegible] DOS [illegible] DOS [illegible] loop [illegible] CON [illegible]
Warning: [illegible]
See Also: INT 28h

INT 2Ah Function 8700h — PRINT v3+
BEGIN BACKGROUND PRINTING

This [illegible] PRINT [illegible] processing [illegible] processes

Called with
AX 8700h
CF clear
Returns
CF clear if OK to print in background now
CF set if background printing not allowed at this time
Notes: When [illegible], it calls this function. If CF is clear [illegible] PRINT [illegible] AX=8701h [illegible]
[illegible] printing while its own code is active
See Also: AH=80h, AH=81h, AX=8701h

INT 2Ah Function 8701h — PRINT v3+ END
BACKGROUND PRINTING

This [illegible] processing

Called with
AX 8701h
Returns
nothing
Note: [illegible] called if AX=8700h returned with CF set
See Also: AX=8700h

INT 2Ah Function 89h — Network
UNKNOWN FUNCTION

The purpose of this function has not been determined

Call With
AH 89h
AL *unknown (ASSIGN uses 00h)*
additional arguments if any unknown
Returns
unknown

INT 2Ah Function C2h — Network
UNKNOWN FUNCTION

The purpose of this function has not been determined

Call With
AH
AL

user password
BX 0001h
other registers

Returns

Note

INT 2Dh — DOS 2+
RESERVED

which make frequent calls through INT 21h. Up to 256
items without conflicts and may be removed in
d on the Interrupt List under INT 21h or in a separate
3.5 as of this

INT 2Eh — DOS 2+
PASS COMMAND TO COMMAND INTERPRETER FOR EXECUTION

Call With
DS:SI pointer to command line to execute (see below)
Returns
all registers except CS:IP destroyed
AX status (if DOS 4.0)
0000h if successful
FFFFh if error before processing command (not enough memory, etc.)
other error codes returned by command

Note
mands without creating another copy of COMMAND.COM
If COMMAND.COM is the user's command interpreter
executes the com
mand line. Does the master environment segment to be modified by issuing a "SET" command, but changes
to the master environment will not become effective
programs descended from the primary
COMMAND.COM command.
needs to be present a
pointer can be allocated by DOS if necessary.
but because this call is not reentrant and COMMAND.COM uses the same internal variables when
processing a batch file

This [illegible] DOS [illegible] COMMAND [illegible] ment unless SHELL2F has been loaded.
This [illegible] MS-DOS Programmer's Reference.
See DO2F.ASM in Chapter 10.

Format of commandline:

Offset	Size	Description
00h	[illegible]	[illegible]
01h	var	command string
N	BYTE	0Dh (CR)

INT 2Fh Function 00h **DOS 2.x only**
PRINT.COM UNKNOWN FUNCTION

The purpose of this function has not been determined.

Call With:
 AH 00h
 additional parameters, if any, unknown

Returns:
 [illegible]

Notes: DOS [illegible] PRINT.COM [illegible]
 Values in AH other than 00h or 01h cause PRINT to return the number of files in the queue in AH.

See Also: INT 2F AH=01h

INT 2Fh Function 0080h **DOS 3.1+**
PRINT.COM GIVE PRINT A TIME SLICE

Allow PRINT to execute for a while.

Call With:
 AX 0080h

Returns:
 after PRINT executes

INT 2Fh Function 0106h **DOS 3.3+**
PRINT.COM GET PRINTER DEVICE

Determine which device PRINT is using for output, if there are any files in the print queue.

Call With:
 AX 0106h

Returns:
 CF set if files in print queue
  AX error code 0008h (queue full)
  DS:SI pointer to device driver header
 CF clear if print queue empty
  AX 0000h

Note: documented for DOS 5+, but not documented for prior versions. (The first edition of Undocumented DOS incorrectly documented this as "Check if Error on Output Device.")

See Also: *2F 0106h*

INT 2Fh Function 0200h **PC LAN REDIR/REDIRIFS**
INSTALLATION CHECK

Determine whether the PC LAN Program redirector is present.

Call With
AX 0208h
Returns
AL FFh if installed

INT 2Fh Functions 0201h to 0204h — PC LAN REDIR/REDIRIFS
UNKNOWN FUNCTIONS

Call With
AX 0201h to 0203h

Returns

Notes: These functions are used by DOS 3.x's PRINT.COM

INT 2Fh Function 0500h — DOS 3+
CRITICAL ERROR HANDLER INSTALLATION CHECK

Called With
AX 0500h
Returns
AL 00h if not installed (DOS 3.x)
01h if not installed (DOS 4.0+)
FFh if installed
Notes:
Used by MS-DOS 3.x's COMMAND.COM
See Also: AX = 5D0Ah, INT 21 AH = 59h

INT 2Fh Function 05h — DOS 3+
CRITICAL ERROR HANDLER EXPAND ERROR INTO STRING

Called With

DOS 3.x

DOS 4.+

Returns

INT 24h AH = 59h error code

DI set if error code can be converted

Notes [illegible] COMMAND.COM [illegible] installed by [illegible] complete control of the default error message Network redirectors should use this [illegible] DOS 4 [illegible] SHARE [illegible]
See Also: INT 2Fh 21 [illegible]

INT 2Fh Function 0600h — DOS 3+
ASSIGN INSTALLATION CHECK

Determine whether ASSIGN has been loaded

Call With
AX 0600h
Returns
AL status
00h not installed
FFh installed but not OK to install
01h OK to install
Note: ASSIGN [illegible] SUBST [illegible]
See Also: 21 52h 21 0601h

INT 2Fh Function 0601h — DOS 3+
ASSIGN GET DRIVE ASSIGNMENT TABLE

[illegible] ASSIGN
Call With
AX 0601h
Returns
ES segment of ASSIGN work area and assignment table
Note: [illegible] mapped to. This table is initially set to 01h 02h 03h
See Also: 21 0600h

INT 2Fh Function 0800h — DOS 3.2+
DRIVER.SYS SUPPORT AVAILABILITY CHECK

Determine [illegible] DRIVER.SYS [illegible] COMMAND.COM
Call With
AX 0800h
Returns
AL 00h not installed OK to install
01h not installed not OK to install
FFh installed
Note: This call is supported by DR DOS 5.0

INT 2Fh Function 0801h — DOS 3.2+
DRIVER.SYS SUPPORT ADD NEW BLOCK DEVICE

Add a new logical drive alias for an existing physical drive
Call With
AX 0801h
DS:DI pointer to drive data table (see 2F:0803h)
Notes [illegible] drive [illegible]

[illegible]
this call is supported by DR DOS v5.0
See Also: AX=0803h

INT 2Fh Function 0802h — DOS 3.2+
DRIVER.SYS SUPPORT - EXECUTE DEVICE DRIVER REQUEST

[illegible] called by [illegible] to execute [illegible] AX=0801h for [illegible] lowering [illegible] requests have been omitted for brevity; the full description may be found on the accompanying disk

Call With:
AX = 0802h
ES:BX = pointer to device driver request header (see below)
Returns:
request header updated as per requested operation
Notes: This function is supported by DR DOS v5.0 [illegible]
[illegible] called [illegible] to switch between DOS and [illegible] see also *DOS Internals*
See Also: AX=0800h, AX=0801h, AX=0803h, 21/52h, 21/99h, 21/9Ah

Values for command code:
00h INIT
[illegible]
12h (European MS-DOS 4.0) Restart Device (for console screen drivers) [illegible]
DOS 3.2+ ignores 00-11
[illegible]
15h (European MS-DOS 4.0) Reset Uncertain Media Flag
16h (reserved)
19h (DOS 5.0+) Check Generic IOCTL Support

Format of device driver request header:

Offset	Size	Description
00h	BYTE	length of request header
01h	BYTE	subunit within device driver
02h	BYTE	command code (see below)
03h	WORD	status (filled in by device driver)
		bit 15: error
		bits 14-11: reserved
		bit 10: unknown; set by DOS kernel on entry to some driver calls
		bit 9: busy
		[illegible] (European MS-DOS 4.0)
		bits 7-0: error code if bit 15 set (see below)
DOS		
05h	4 BYTEs	reserved (unused in DOS 2.x and 3.x)
[illegible]		[illegible] (DOS 4.0) [illegible] request
		on device's request queue
		[illegible] DOS 2.x and 3.x
—STARLITE architecture—		
[illegible]	DWORD	pointer to next request header
09h	4 BYTEs	reserved

—command code 00h—

0Dh	BYTE	(return) number of units
0Eh	DWORD	call: pointer to DOS device helper function (see below European MS-DOS 4.0 only) call: pointer past end of memory available to driver (DOS 5.0+) return: address of first free byte following driver
12h	DWORD	call: pointer to command line arguments ret (+): pointer to BPB array (block drivers) or 0000h 0000h (character devices)
16h	BYTE	DOS 3+: drive number for first unit of block driver (0=A)

—European MS-DOS 4.0—

17h	DWORD	pointer to function to save registers on stack

—DOS 5+—

17h	WORD	return: error message flag: set to 0001h for MS DOS to display error message on initialization failure

—command codes 11h,12h—

0Dh	BYTE	reserved

—command code 15h—

no further fields

—command codes 13h,19h—

0Dh	BYTE	category code 00h unknown 01h COMn 03h CON 05h LPTn 07h mouse (European MS-DOS 4.0) 08h disk 09h "STARTTEC" Media Access Control driver
0Eh	BYTE	function code 00h ("STARTTEC") MAC Bind request
0Fh	WORD	copy of SI at time of DOS IOCTL call (apparently unused in DOS 3.3+) SI contents: European MS-DOS 4.0: reserved; DOS 5.0:
11h	WORD	offset of device driver header DI contents: European MS-DOS 4.0: reserved; DOS 5.0:
13h	DWORD	pointer to parameter block from 21.4400h or AX=4409h

Values for error code:

00h write protect violation
01h unknown unit
02h drive not ready
03h unknown command
04h CRC error
05h bad drive request structure length
06h seek error
07h unknown media
08h sector not found
09h printer out of paper
0Ah write fault
0Bh read fault
0Ch general failure
0Dh reserved
0Eh (CD-ROM) media unavailable

0Fh invalid disk change

Call European MS-DOS 4.0 device helper function with:

DL = function

00h "SchedClock" called on each timer tick

AL = clock interval in milliseconds

01h "DevDone" device I/O complete

ES:BX = pointer to request header

Note: [illegible] should not be called from an interrupt handler

02h "PullRequest" pull next request from queue

DS:SI = [illegible] DWORD pointer to start of device's request queue

Return: /F clear if pending request

ES:BX = pointer to request header

/F set if no more requests

03h "PullParticular" remove specific request from queue

DS:SI = [illegible] DWORD pointer to start of device's request queue

ES:BX = pointer to request header

Return: /F set if request header not found

04h "PushRequest" push the request onto the queue

DS:SI = [illegible] DWORD pointer to start of device's request queue

ES:BX = [illegible] request header

interrupts disabled

05h "CooperativeWait" keyboard input check

AX = character (high byte 00h if PC-ANSI character)

Return: /F set if character should be discarded

/F clear if character should be handled normally

Note: [illegible] used internally by DOS to wait for special input characters

Do not call [illegible] from critical section; [illegible] switching occurs

DS:SI = [illegible] DWORD pointer to start of device's request queue

ES:BX = pointer to request header

interrupts disabled

07h "SigEvent" send signal on keyboard event

AH = event identifier

Return: AL, BH, DX destroyed

09h "ProcBlock" block on event

AX:BX = event identifier (typically a pointer)

CX = timeout in ms or 0000h for never

[illegible] set to 0 [illegible] set to 1 if interrupted

interrupts disabled

Return: after corresponding ProcRun call

CF clear if event wakeup, set if unusual wakeup

/F set if timeout wakeup, clear if interrupted

AL = wakeup code (nonzero if unusual wakeup)

interrupts enabled

BX, CX, DX destroyed

Note: blocks process and schedules another to run

0Ah "ProcRun" unblock process

AX:BX = event identifier (typically a pointer)

Return: AX = number of processes awakened

/F set if no processes awakened

BX, CX, DX destroyed

0Bh "QueueInit" initialize clear character queue

DS:BX = pointer to character queue structure (see below)
Note: the queue size field must be set before calling
0Dh "QueueWrite" put a character in the queue
DS:BX = pointer to character queue (see below)
AL = character to append to end of queue
Return: ZF set if queue is full
ZF clear if character stored
0Eh "QueueRead" get a character from the queue
DS:BX = pointer to character queue (see below)
Return: ZF set if queue is empty
ZF clear if characters in queue
AL = first character in queue
10h "GetDOSVar" return pointer to DOS variable
AL = index of variable
03h current process ID
BX = index into variable if AL specifies an array
CX = expected length of variable
Return: CF clear if successful
DX:AX = pointer to variable
CF set on error
AX,DX destroyed
BX,CX destroyed
Note: the variables may not be modified
14h "Yield" yield CPU if higher priority task ready to run
Return: all MOS destroyed
1Bh "CritEnter" begin system critical section
DS:BX = pointer to semaphore (6 BYTEs, initialized to zero)
Return: AX,BX,CX,DX destroyed
1Ch "CritLeave" end system critical section
DS:BX = pointer to semaphore (6 BYTEs, initialized to zero)
Return: AX,BX,CX,DX destroyed
Note: must be called in the context of the process which called CritEnter on the semaphore

Note: The DWORD pointing at the request queue must be allocated by the driver and initialized to 0000h:0000h. It always points at the next request to be executed.

Format of character queue:

Offset	Size	Description
00h	WORD	size of queue in bytes
02h	WORD	index of next character out
04h	WORD	count of characters in the queue
06h	N BYTEs	queue buffer

INT 2Fh Function 0803h — DOS 4+

DRIVER.SYS support — GET DRIVE DATA TABLE LIST

Return a pointer to the first in a list of drive data tables describing the layout of the logical drives supported by the combination of the default disk device driver and aliases established with DRIVER.SYS

Call With
AX 0803h

Returns
DS:DI pointer to first drive data table in list
Note: This function is not available under DR DOS 5.0
See Also: 21 0801h

Format of DOS 3.30 drive data table:

Offset	Size	Description
00h	DWORD	pointer to next table
04h	BYTE	physical unit number (for INT 13h)
05h	BYTE	logical drive number (0=A)
06h	19 BYTEs	BIOS Parameter Block (see also 21 53h)

Offset	Size	Description
00h	WORD	bytes per sector
02h	BYTE	sectors per cluster, FFh if unknown
03h	WORD	number of reserved sectors
05h	BYTE	number of FATs
06h	WORD	number of root dir entries
08h	WORD	total sectors
0Ah	BYTE	media descriptor, 00h if unknown
0Bh	WORD	sectors per FAT
0Dh	WORD	sectors per track
0Fh	WORD	number of heads
11h	WORD	number of hidden sectors

Offset	Size	Description
19h	BYTE	[illegible] 16-bit FAT instead of 12 bit FAT
[illegible]	WORD	[illegible] DEVICE OPEN [illegible] corresponding DEVICE CLOSE
[illegible]	[illegible]	[illegible] "NO NAME" [illegible] "NO NAME" [illegible]
27h	BYTE	*terminating null for volume label*
28h	BYTE	device type (see 21 440Dh)
29h	WORD	bit flags describing drive 0 fixed media door lock supported *unknown (used in determining BPB to set for 21 440Dh)* all sectors in a track are the same size physical drive has multiple logical units current logical drive for physical drive [illegible] 8 *related to disk change detection*
2Bh	WORD	[illegible]
2Dh	19 BYTEs	BIOS [illegible] Block [illegible] supported
40h	*4 BYTEs*	*unknown*
43h	*9 BYTEs*	*filesystem type, default is "NO NAME"* [illegible] MS-DOS 5.0 [illegible] for removable media and PC DOS 3.30
[illegible]	[illegible]	[illegible] number

—removable media—

Offset	Size	Description
4Dh	DWORD	[illegible] FFFFFFFFh if never

fixed media—

Offset	Size	Description
4Dh	WORD	[illegible] 0000h [illegible] restricted

4Fh	WORD	absolute cylinder number of partition's start on physical drive (always FFFFh if primary partition)

Format of COMPAQ DOS 3.31 drive data table:

Offset	Size	Description
00h	DWORD	pointer to next table
04h	BYTE	physical unit number (for INT 13h)
05h	BYTE	logical drive number (0=A:)
06h	25 BYTEs	BIOS Parameter Block (see DOS 4.01 drive data table below)
1Fh	*6 BYTEs*	*apparently always zero*
25h	BYTE	flags bit 0: 16-bit FAT instead of 12-bit FAT bit 5: *large volume*
26h	*WORD*	*(unknown)*
28h	11 BYTEs	volume label or "NO NAME" (root always "NO NAME" for fixed media)
33h	BYTE	terminating null for volume label
34h	BYTE	device type (see 21-440[3]h)
35h	WORD	bit flags describing drive
37h	WORD	number of cylinders
39h	25 BYTEs	BIOS parameter block for highest capacity drive supports
52h	*6 BYTEs*	*apparently always zero*
58h	BYTE	least significant byte of last accessed cylinder number
—removable media—		
59h	DWORD	time of last access (clock ticks, FFFFFFFFh if never)
—fixed media—		
59h	WORD	partition (FFFFh if primary, 0001h if extended)
5Bh	WORD	absolute cylinder number of partition's start on physical drive (always FFFFh if primary partition)

Format of DOS 4.0-6.0 drive data table:

Offset	Size	Description
00h	DWORD	pointer to next table
04h	BYTE	physical unit number (for INT 13h)
05h	BYTE	logical drive number (0=A:)
06h	25 BYTEs	BIOS Parameter Block (see also 21-53h)

Offset	Size	Description
00h	WORD	bytes per sector
02h	BYTE	sectors per cluster (1 if bulk/tape)
03h	WORD	number of reserved sectors
05h	BYTE	number of FATs
06h	WORD	number of root directories
08h	WORD	total sectors (see offset 15h if zero)
0Ah	BYTE	media descriptor (00h if unknown)
0Bh	WORD	sectors per FAT
0Dh	WORD	sectors per track
0Fh	WORD	number of heads
11h	DWORD	number of hidden sectors
15h	DWORD	total sectors if WORD at 08h is zero

19h	BYTE	file system flags bit 6: 16-bit FAT instead of 12-bit bit 7: unsupportable disk, all accesses will return Not Ready
20h	*2 BYTEs*	*device-open count*

	BYTE	device type (see AX=4400h)
	WORD	bit flags describing drive
		bit 0 removable media
		bit 1 door lock supported
		bit 2 current BPB locked
		bit 3 all sectors in a track are the same size
		bit 4 physical drive has multiple logical units
		bit 5 current logical drive for physical drive
		bit 6 disk change detected
		bit 7 set DASD before formatting
		bit 8 disk reformatted
		bit 9 read/writes disabled
25h	WORD	number of cylinders
		DOS 5+ maximum clock for [illegible] supported
00h	BYTE	[illegible]

removable media

		[illegible]

fixed media

		[illegible]
		0001h for DOS 5+
2	WORD	[illegible]
		FFFFh if primary partition in DOS 4.x
		[illegible]
		[illegible]
57h	DWORD	[illegible]
		[illegible]
63h	BYTE	*terminating null for filesystem type*

INT 2Fh Function 1000h — DOS 3+

SHARE - INSTALLATION CHECK

Determine whether SHARE has been loaded

On Entry:

AX	1000h

Returns:

AL	00h not installed, OK to install
	01h not installed, not OK to install
	FFh installed

Notes: [illegible] DOS 3.x SHARE, not PC-DOS 4.0's new advanced version of SHARE, which returns AL=FFh [illegible] DOS 3.x [illegible] SHARE is supported by installing its own INT 2Fh handler [illegible] this call is made

DOS 5+ chains to the previous handler if AL <> 00h on entry

[illegible] DOS 5.0

AL=01h [illegible] SHARE's status [illegible] what it is not. See IS SHARE OK in Chapter 8

See Also: AX=52h, AX=1080h

INT 2Fh Function 1080h — DOS 4.x only
SHARE TURN ON FILE SHARING CHECKS

Enable access checking modes that are ignored when SHARE is not present on large partitions

Call With
AX 1080h
Returns
AL status
00h successful
01h checking was already on
See Also: 2F 1000h 2F 1081h

INT 2Fh Function 1081h — DOS 4.x only
SHARE TURN OFF FILE SHARING CHECKS

Disable access checking modes that are ignored when SHARE is not present on large partitions

Call With
AX 1081h
Returns
AL status
00h successful
01h checking was already off
See Also: 2F 1000h 2F 1080h

INT 2Fh Function 1100h — DOS 3.1+
NETWORK REDIRECTOR INSTALLATION CHECK

Call With
AX 1100
Returns
AL
01h installed
Notes: This function is called by the DOS 3.1+ kernel

INT 2Fh Function 1100h — MSCDEX
INSTALLATION CHECK

Call With
AX 1100h
STACK WORD DATA
Returns
AL 00h not installed, OK to install

SI MC K unchanged
Dh not installed--not OK to install
SI MC K unchanged
+Dx installed
SI MC K = WORD AD ADS

INT 2Fh Function 1101h — DOS 3.1+
NETWORK REDIRECTOR - REMOVE REMOTE DIRECTORY

[illegible] a directory on a network or installable file system drive

Called With:
- AX = 1101h
- SS:SI = DOS DS
- SDA first filename pointer = pointer to fully qualified directory name
- SDA CDS pointer = pointer to current directory structure for drive with dir

Returns:
- CF set = [illegible]
  - AX = DOS error code (see AH=59h)
- CF clear = successful

Notes: [illegible]

See Also: AH=52h, 2Fh/1102h, 2Fh/1103h, AH=1103h, AH=1105h

INT 2Fh Function 1102h — DOS 4.x only
IFSFUNC.EXE - REMOVE REMOTE DIRECTORY

Remove a directory on a network or installable file system drive

Called With:
- AX = 1102h
- SS = DOS DS
- SDA first filename pointer = [illegible] directory name
- SDA CDS pointer = [illegible] ucture for drive with dir

Returns:
- CF set on error
  - AX = DOS error code (see AH=59h)
- CF clear if successful

Note: This function appears to be identical to AX=1101h

See Also: AH=1103h

INT 2Fh Function 1103h — DOS 3.1+
NETWORK REDIRECTOR - MAKE REMOTE DIRECTORY

Create a new directory on a network or installable file system drive

Called With:
- AX = 1103h
- SS = DOS DS
- SDA first filename pointer = pointer to fully qualified directory name
- SDA CDS pointer = pointer to current directory structure for drive with dir

Returns:
- CF set on error
  - AX = DOS error code (see AH=59h)
- CF clear if successful

Notes: [illegible] function is called by the DOS 3.1+ ke

See Also: AH=59h, 2Fh/1101h, 2Fh/1102h, AH=1105h

INT 2Fh Function 1104h — DOS 4.x only
IFSFUNC.EXE MAKE REMOTE DIRECTORY

Create a new directory on a network or installable file system drive

Called With
- AX 1104h
- SS DOS DS see 2F 1203h
- SDA [illegible] pointer to [illegible]
- SDA [illegible] pointer to [illegible]

Returns
- CF set on error
  - AX DOS error code see *21 59h*
- CF clear if successful

Note [illegible] 21 1107h
See Also: 2F 1103h

INT 2Fh Function 1105h — DOS 3.1+
NETWORK REDIRECTOR CHDIR

Change [illegible] directory on a network or installable file system drive

Called With
- AX 1105h
- SS DOS DS see 2F 1203h
- SDA [illegible] pointer to [illegible]
- SDA [illegible] pointer to [illegible]

Returns
- CF set on error
  - AX DOS error code see *21 59h*
- CF clear if successful
  - CDS updated with new path

Notes: [illegible] 35

[illegible] directory is the root directory
See Also: *21 38h*, 21 60h, 21 1101h, 21 1103h

INT 2Fh Function 1106h — DOS 3.1+
NETWORK REDIRECTOR CLOSE REMOTE FILE

Close [illegible] opened on a network or installable file system drive

Called With
- AX 1106h
- ES DI pointer to SFT
  - SFT [illegible] pointer to [illegible] DI [illegible]

Returns
- CF set on error
  - AX DOS error code see *21 59h*
- CF clear if successful
  - SFT [illegible] 2F 1208h

Note: This function is called by the DOS 3.1+ kernel

[illegible] SFT; see also PHANTOM.C and 2F=1208 in Chapter 8
See Also: 2F=1106h, 2F=1201h, 2F=122Fh

INT 2Fh Function 1107h — DOS 3.1+
NETWORK REDIRECTOR COMMIT REMOTE FILE

[illegible] and disk buffers for a file on a network or installable file system drive
Called With
AX 1107h
ES:DI pointer to SFT
SFT DPB field pointer to DPB of drive containing file
Returns
CF set on error
AX DOS error code, see 21=59h
CF clear if successful
all buffers for file flushed
directory entry updated
Note: This function is called by the DOS 3.1+ kernel
See Also: 21=5D01h, 21=68h

INT 2Fh Function 1108h — DOS 3.1+
NETWORK REDIRECTOR READ FROM REMOTE FILE

[illegible] for a file on a network or installable file system drive
Called With
AX 1108h
CX number of bytes
SS DOS DS, see 2F=1203h0
SDA DTA field pointer to user buffer
ES:DI pointer to SFT
SFT DPB field pointer to DPB of drive containing file
Returns
CF set on error
AX DOS error code, see 21=59h
CF clear if successful
CX number of bytes read (0000h if at end of file)
SFT updated
Note: [illegible] DOS [illegible] for [illegible]; see Ralf Brown's Interrupt List, Volume 8, pages 8-30 and 8-31
See Also: 2F=1106h, 2F=1108h, 2F=1109h, 2F=1229h

INT 2Fh Function 1109h — DOS 3.1+
NETWORK REDIRECTOR WRITE TO REMOTE FILE

[illegible] for a file on a network or installable file system drive

Called With
AX 1109h
CX number of bytes
SS DOS DS
SDA DTA field pointer to user buffer
ES:DI pointer to SFT
SFT DPB field pointer to DPB of drive co[illegible]

Returns
CF set on error
AX DOS error code (see *21-59h*)
CF clear if successful
CX number of bytes written
SFT updated
Note: This function is called by the DOS 3.1+ kernel
See Also: *21-440h*, *21-5F06h*, *2F-1107h*, *2F-1108h*

INT 2Fh Function 110Ah — DOS 3.1-3.31 only
NETWORK REDIRECTOR - LOCK REGION OF FILE

Request that no other processes be allowed access to a portion of the specified file

Called With
AX 110Ah
BX file handle
CX:DX starting offset
SI high word of size
SS DOS DS (see *2F-1203h*)
ES:DI pointer to SFT
SFT+2Ah (word) pointer to DPB of drive containing file
STACK WORD low word of size
Returns
CF set on error
AL DOS error code (see *21-59h*)
STACK unchanged
Notes: This function is called by the DOS 3.10-3.31 kernel. The redirector is expected to resolve lock conflicts
See Also: *21-5C0h*, *2F-110Bh*

INT 2Fh Function 110Ah — DOS 4+
NETWORK REDIRECTOR - LOCK/UNLOCK REGION OF FILE

Deny or allow access to a portion of a remote file by other processes

Called With
AX 110Ah
BL function
00h lock
01h unlock
DS:DX pointer to parameter block (see below)
SS DOS DS
ES:DI pointer to SFT
SFT+2Ah (word) pointer to DPB of drive containing file
Returns:
CF set on error
AL DOS error code (see *21-59h*)
Notes: This function is called by the DOS 4.0+ kernel
The redirector is expected to resolve lock conflicts
See Also: *21-5C0h*, *2F-110Bh*

Format of parameter block

Offset	Size	Description
00h	DWORD	start offset
04h	DWORD	size of region

INT 2Fh Function 110Bh — DOS 3.1 3.31 only

NETWORK REDIRECTOR UNLOCK REGION OF FILE

Allow other processes to access the specified portion of the file

Called With
- AX 110Bh
- BX file handle
- SI high word of size
- STACK WORD low word
- DS:DI pointer to SFT for
  - SFT_PSP_fcb pointer to PSP that owns exclusive lock

Returns
- CF set on error
  - AL DOS error code (see
- STACK not removed

Note
See Also

INT 2Fh Function 110Ch — DOS 3.1+

NETWORK REDIRECTOR GET DISK SPACE

Get disk space for a network drive

Called With
- AX 110Ch
- DS:DI pointer to current directory structure

Returns
- AL sectors/cluster
- AH media ID byte
- BX total clusters
- CX bytes per sector
- DX available clusters

Note
See Also

INT 2Fh Function 110Eh — DOS 3.1+

NETWORK REDIRECTOR SET REMOTE FILE'S ATTRIBUTES

Change the attributes of a file on a network or custom block device drive

Called With
- AX 110Eh
- SS DOS DS
- SDA first filename pointer
- SDA CDS pointer
- STACK WORD low

Returns
CF set on error
AX DOS error code (see *21 59h*)
CF clear if successful
SDA unchanged
Note This function is called by the DOS 3.1+ kernel
See Also *21 4301h*, *21 5D0Bh*, *2F 110Fh*

INT 2Fh Function 110Fh — DOS 3.1+
Network Redirector - Get Remote File's Attributes And Size

Get file attributes and size for network or installable file system file

Called With
AX 110Fh
SS DOS DS
SDA [illegible] pointer
SDA CDS pointer pointer to current directory structure for drive with file
Returns
CF set on error
AX DOS error code (see *21 59h*)
CF clear if successful
AX file attributes
BX:DI file size
Note This function is called by the DOS 3.1+ kernel
See Also *21 4300h*, *21 5D0Bh*, *2F 1106h*

INT 2Fh Function 1111h — DOS 3.1+
NETWORK REDIRECTOR - RENAME REMOTE FILE

Rename a file on a network or installable file system drive

Called With
AX 1111h
SS DOS DS
DS DOS DS
SDA first filename pointer pointer to fully qualified old name
SDA second filename pointer pointer to fully qualified new name
SDA CDS pointer pointer to current directory structure for drive with file
Returns
CF set on error
AX DOS error code (see *21 59h*)
CF clear if successful
Note This function is called by the DOS 3.1+ kernel
See Also *21 56h*, *21 60h*

INT 2Fh Function 1113h — DOS 3.1+
NETWORK REDIRECTOR - DELETE REMOTE FILE

Remove a file from a network or installable file system drive

Called With
AX 1113h
SS DOS DS

DS DOS DS

Returns

DOS error code (see 21,59h)
CF clear (successful)
Notes: This function is called by the DOS 3.1+ kernel
Device specifications may contain wildcards
See Also: 21,41h 21,60h

INT 2Fh Function 1116h — DOS 3.1+
NETWORK REDIRECTOR - OPEN EXISTING REMOTE FILE

Prepare for access to an existing file located on a network drive

Called With:
AX 1116h
ES:DI pointer to uninitialized SFT
SS DOS DS
SI:AC pointer to ASCIZ file name (see 21,3Dh)
SI:ACK WORD file open mode (see 21,3Dh)
Returns:
CF set on error
AX DOS error code (see 21,59h)
CF clear on success
SFT filled (except handle count which DOS manages itself)
SI:ACK unchanged
Notes: This function is called by the DOS 3.1+ kernel
See Also: 21,59h, 21,60h, 21,6100h, 21,1117h, 2F,1123h

INT 2Fh Function 1117h — DOS 3.1+
Network Redirector - Create/truncate Remote File With CDS

Create a file on a network drive or truncate an existing file to zero length

Called With:
AX 1117h
ES:DI pointer to uninitialized SFT
SS DOS DS
SDA[SDA_wSpecPtr] pointer to fully qualified name of file to open
SI:ACK WORD file creation mode
low byte: file attributes
high byte: 00h if normal create, 01h create new file
Returns:
CF set on error
AX DOS error code (see 21,59h)
CF clear on success
SFT filled (except handle count which DOS manages itself)
SI:ACK unchanged
Note: This function is called by the DOS 3.1+ kernel
See Also: 21,5Bh, 21,6Ch, 21,6900h, 2F,1123h

INT 2Fh Function 1118h — DOS 3.1+

Network Redirector Create/truncate File Without Cds

Create a file on a drive which does not have a current directory structure

Called With

AX	1118h
ES:DI	pointer to uninitialized SF1
SS	DOS DS
SDA first filename pointer	pointer to [illegible]
STACK	WORD file creation mode low byte = file attributes high byte = 00h normal create, 01h create new file

Returns

nothing new
STACK unchanged

Note [illegible] DOS 3.1 [illegible] SDA CDS [illegible] DOS [illegible] 21 11 [illegible] 21 56
Create New File for the name "FOO.BAR"
See Also: 21 [illegible] 2F 1106h, 2F 1116h, 2F 1117h, 21 1D1

INT 2Fh Function 1119h — DOS 3.1+

NETWORK REDIRECTOR FIND FIRST FILE WITHOUT CDS

Begin [illegible] search on a network drive. Does not have a CDS [illegible]

Called With

AX	1119h
SS	DOS DS
DS	DOS DS
[illegible]	[illegible]
SDA first filename [illegible]	[illegible]
SDA search attr [illegible]	[illegible]

Returns

CF set on error
AX DOS error code (see *21 59h*)
CF clear if successful
AX [illegible]
bit 7 of first byte must be set
[DTA+15h] standard directory entry for file

Notes: This function [illegible] DOS [illegible] DH, [illegible] AX
DOS 4.x IFSFUNC returns CF set, AX=0003h

INT 2Fh Function 111Bh — DOS 3.1+

NETWORK REDIRECTOR - FINDFIRST

Begin a directory search on a network or [illegible]

Called With:

AX	111Bh
SS	DOS DS
DS	DOS DS
[illegible]	[illegible]
SDA first [illegible]	pointer to [illegible]

SDA search attribute attribute mask for search

Returns

CF set on error

AX DOS error code (see *21 59h*)

CF clear if successful

DTA updated findfirst search data

(byte 0 of first byte must be set)

DTA+15h standard directory entry for file

Note

See Also *21 4Eh, 21 60h, 21 111Ch*

INT 2Fh Function 111Ch — DOS 3.1+

NETWORK REDIRECTOR FINDNEXT

Continues a directory search on a network or host-able file system drive

Called With

AX

DS DOS DS

DTA 21 byte findfirst search data (see *21 4Eh*)

Returns

CF set on error

AX DOS error code (see *21 59h*)

CF clear if successful

DTA updated findfirst search data

(byte 0 of first byte must be set)

DTA+15h standard directory entry for file

Note

See Also *21 4Fh, 21 111Bh*

INT 2Fh Function 111Dh — DOS 3.1+

Network Redirector Close All Remote Files For Process

Called With

AX 111Dh

DS

SS DOS DS

Returns

Notes: Undocumented, called by the DOS 3.1+ kernel

The redirector also closes all FCBs opened by the process

See Also *2F 1034*

INT 2Fh Function 111Eh — DOS 3.1+

NETWORK REDIRECTOR DO REDIRECTION

Various subfunctions allow control of network redirection

Called With

AX 111Eh

SS DOS DS

STACK WORD function to execute

5F00h get redirection mode
BL type (03h printer, 04h disk)
Returns:
BH state (00h off, 01h on)
5F01h set redirection mode
BL type (03h printer, 04h disk)
BH state (00h off, 01h on)
5F02h get redirection list entry
BX redirection list index
DS:SI pointer to 16 byte local device name buffer
ES:DI pointer to 128 byte network name buffer
Returns:
must set user's BX to device type and CX to stored parameter value using 21 1218h to get stack frame address
5F03h redirect device
BL device type (see *21 5F03h*)
CX stored parameter value
DS:SI pointer to ASCIZ source device name
ES:DI pointer to destination ASCIZ network path + ASCIZ passwd
5F04h cancel redirection
DS:SI pointer to ASCIZ device name or network path
5F05h get redirection list extended entry
BX redirection list index
DS:SI pointer to buffer for ASCIZ source device name
ES:DI pointer to buffer for destination ASCIZ network path
Returns:
BH status flag
BL type (03h printer, 04h disk
CX stored parameter value
BP NETBIOS local session number
5F06h similar to 5F05h

Returns
CF set on error
AX error code (see *21 59h*)
STACK unchanged
Note: This function is called by the DOS 3.1+ kernel on 21 5Fh (including LAN Manager calls)
See Also: 21 5F00h, 21 5F01h, *21 5F02h*, *21 5F03h*, *21 5F04h*, 21 5F05h, 21 5F06h

---

INT 2Fh Function 111Fh — DOS 3.1+
NETWORK REDIRECTOR - PRINTER SETUP

Subfunctions allow getting or setting the network printer setup string or mode

Called With
AX 111Fh
STACK WORD function
5E02h set printer setup
5F03h get printer setup
5F04h set printer mode
5F05h get printer mode

Returns:
CF set on error

AX error code (see *21/59h*)
STACK unchanged

Note: This function is called by the DOS 3.1+ kernel on 21/5D
See Also: *21/5E02h, 21/5E03h, 21/5E04h, 21/5E05h*

INT 2Fh Function 1120h — DOS 3.1+
NETWORK REDIRECTOR — FLUSH ALL DISK BUFFERS

[illegible] from disk buffers which [illegible] yet been written out to disk

Called With

AX	1120h
DS	DOS DS

additional arguments, if any, unknown

Returns

CF clear successful

Notes: This function is called by the DOS 3.1+ kernel
[illegible] CLASTDRIVE [illegible] DOS list of lists [illegible]
used by the DOS 4 RESET NC handler for this call
See Also: *21/0Dh, 21/5D01h*

INT 2Fh Function 1121h — DOS 3.1+
NETWORK REDIRECTOR — SEEK FROM END OF REMOTE FILE

Set the file pointer relative to the end of the specified file

Called With

AX	1121h
SS	DOS DS
CX:DX	offset (in bytes) from end
ES:DI	pointer to SFT
SFT DPB field	pointer to DPB of drive with file

Returns

CF set on error
AL DOS error code (see *21/59h*)
CF clear if successful
DX:AX new file position

Notes: [illegible] Chapter 8 when setting [illegible]

See Also: [illegible]

INT 2Fh Function 1122h — DOS 3.1+
NETWORK REDIRECTOR — PROCESS TERMINATION HOOK

Inform the network that a process has terminated

Called With

AX	1122h
SS	DOS DS
DS	PSP of process about to terminate

additional arguments, if any, unknown

Returns
[illegible]
Note: This function is called by the DOS 3.1+ kernel

INT 2Fh Function 1123h — DOS 3.1+
NETWORK REDIRECTOR QUALIFY REMOTE FILENAME

Convert a name into a canonical path name with any network redirections resolved
Called With
AX 1123h
DS:SI pointer to ASCIZ filename to canonicalize
ES:DI pointer to 128 byte buffer for qualified name
Returns
CF set if not resolved
Notes: This function is called by the MS-DOS 4.x kernel but not by DR-DOS 5.0 or later to handle device names or to canonicalize a character device
DOS 4.x calls this function with bit 0 of BL set to request that the redirector attempt to resolve the name using the server call, if this fails, DOS resolves the name locally
See Also: 21/60h, 2F/1221h

INT 2Fh Function 1124h — DOS 3.1+
NETWORK REDIRECTOR PRINTER OFF

Appears to close printer associated with standard output prior to the DEL string
Called With
AX 1124h
DS:SI pointer to SFT
SS DOS DS
[illegible] segment if any unknown
Returns
CX [illegible]

Note: This function is called by the DOS 3.1+ kernel for 21/112Eh if redirected output is set
See Also: 21/112Eh

INT 2Fh Function 1125h — DOS 3.1+
NETWORK REDIRECTOR REDIRECTED PRINTER MODE

Set or retrieve the state of print streams for the network printer

Called With
AX 1125h
STACK WORD subfunction
5D07h get print stream state
Returns
DL current state
5D08h set print stream state
DL new state
5D09h flush print job
Returns:
CF set on error
AX error code (see 21/59h)
STACK unchanged
Note: This function is called by the DOS 3.1+ kernel
See Also: 21/5D07h, 21/5D08h, 21/5D09h

INT 2Fh Function 1126h — DOS 3.1+
NETWORK REDIRECTOR PRINTER ON/OFF

[illegible] printer echo of standard output

Called With
- AX 1126h
- ES:DI *pointer to SFT for file handle 4*
- SS DOS DS (see 21 1203h)
- *additional arguments if any unknown*

Returns
- CF set on error

Note [illegible] PrtSc changes state [illegible]

See Also: 21 1124h

INT 21h Function 1127h — Novell
NETWORK REDIRECTOR REMOTE COPY

[illegible] for more information see chapter 8

INT 2Fh Function 112Bh — DOS 4.x only
IFSFUNC EXE GENERIC IOCTL

Implements the "Generic IOCTL" call on network devices

Called With:
- AX 112Bh
- SS DOS DS
- CX function category
- DS:DX pointer to parameter block
- STACK WORD ID [illegible]
- *additional arguments if*

Returns
- CF set on error
  - AX DOS error code (see *21 59h*)
- CF clear if successful

Note: this function is called by the DOS 4.0 kernel

INT 2Fh Function 112Ch — DOS 4+
IFSFUNC EXE UNKNOWN FUNCTION

The purpose of this function has not been determined

Called With
- AX 112Ch
- SS DOS DS
- SDA current SFT ptr pointer [illegible]
- *additional arguments if any*

Returns
- CF set on error
  - AX DOS error code (see *21 59h*)
- CF clear if successful

Note: Called by SHARE in DOS 3.0

INT 2Fh Function 112Dh — DOS 4.x only

IFSFUNC.EXE - UNKNOWN FUNCTION

The purpose of this function has not been determined

Called With

AX 112Dh
BL subfunction value of AL on INT 21h
04h truncate open file to zero length
ES:DI pointer to SFT for file
Returns:
CF clear
else unknown
Returns
CX *unknown (00h or 02h for DOS 4.01)*
ES:DI pointer to SFT
SS DOS DS

Returns:

DS DOS DS

Note: This function is called by the DOS 4.0 kernel on 21 5702h, 21 5703h, and 21 5704h. Perhaps 2F 112D supports OS/2 extended attributes (EAs) and/or the Dosstar SetPath Exclude functions

INT 2Fh Function 112Eh — DOS 4+

NETWORK REDIRECTOR EXTENDED OPEN/CREATE FILE

Implements the extended file open/create call 21 6Ch for network and installable file system drives

Called With

AX	112Eh
SS	DOS DS
DS	DOS DS
ES:DI	pointer to uninitialized SFT for file
SDA ext fcb name pointer	pointer to file specified (unopened)
SDA extended file open mode	action code (see 21 6C00)
SDA extended file open attrib	open mode (see 21 6C00)
STACK	WORD Flags (CX for created/truncated file)
	low byte = file attributes
	high byte = 00h to fail create, open file, create new file

Returns

CF set on error
AX error code
CF clear if success
CX result code
01h file opened
02h file created
03h file replaced (truncated)
SFT in ES:DI initialized (except for file count which DOS manages itself)

Note: This function is called by the DOS 4+ kernel and by DOS 3+ SHARE

See Also *21 6C00*, 2F 1105, 2F 1216h, 2F 1117h

INT 2Fh Function 1130h — DOS 4.x only
IFSFUNC.EXE GET IFSFUNC SEGMENT

Return the segment of the resident IFSFUNC code

Called With
- AX 1130h

Returns
- ES Segment of resident IFSFUNC

INT 2Fh Function 1200h — DOS 3+
INTERNAL FUNCTIONS AVAILABILITY CHECK

Determine whether the DOS internal services are present

Call With
- AX 1200h

Returns
- AL FFh if internal services installed, else 00h
- BX 3457h if internal services installed, else undefined

Note: See Chapters 6 and 8 for discussions of the DOS internal functions

INT 2Fh Function 1201h — DOS 3+
CLOSE CURRENT FILE

Close the file currently being operated on

Call With
- AX 1201h
- SS DOS DS
- SDA current SFT pointer pointer to SFT of file to close

Returns
- CF set on error
- CF clear if successful
  - BX *unknown*
  - CX new reference count of SFT
  - ES:DI pointer to SFT for file

See Also: *AH = 3Eh* 21, 1106h 21, 1237h

INT 2Fh Function 1202h — DOS 3+
GET INTERRUPT ADDRESS

Return the address stored in the specified interrupt number

Call With
- AX 1202h
- STACK WORD interrupt number

Returns
- ES:BX pointer to interrupt
- STACK unchanged

INT 2Fh Function 1203h — DOS 3+
GET DOS DATA SEGMENT

Return the segment of the ALLDOS DATA SEG (DOSSYS data area)

Call With
- AX 1203h

Returns
DS segment of IBMDOS.COM/MS-DOS.SYS data segment

Note: For DOS 3.X and 4.X, but *not* for DOS 5+, the kernel code segment is the same as the data segment.

Many Microsoft products call undocumented DOS functions by searching for and using INT 21/AH=52h and using ES:(-0002h) or BX:[0] The "style" (DOS 3 or DOS 4+) of the DOS data segment is indicated by the byte at offset 4 of DOSDS (see INT 21/AH=5200h)

INT 2Fh Function 1204h — DOS 3+
NORMALIZE PATH SEPARATOR

Convert forward slashes into backslashes

Call With
AX 1204h
STACK WORD character to normalize
Returns
AL [illegible]
ZF set if path separator
STACK unchanged

INT 2Fh Function 1205h — DOS 3+
OUTPUT CHARACTER TO STANDARD OUTPUT

Send a single character to the standard output of [illegible]

Call With
AX 1205h
STACK WORD character to output
Returns
STACK unchanged
Note: [illegible] DOS [illegible]

INT 2Fh Function 1206h — DOS 3+
INVOKE CRITICAL ERROR

[illegible] INT 24h [illegible]

Call With
AX 1206h
DI error code
BP:SI pointer to device driver [illegible]
SS DOS DS
STACK WORD value to be passed to INT 24h in AX
Returns
AL 0-3 for Abort, Retry, Ignore, Fail
STACK unchanged
See Also: INT 24h

INT 2Fh Function 1207h — DOS 3+
MAKE DISK BUFFER MOST RECENTLY USED

Move [illegible] to the most recently used position in the disk buffer chain, thereby [illegible] the least recently used

Call With
AX 120Bh
DS:DI pointer to disk buffer
Returns

Note [illegible] to be called from within a DOS to sector call
[illegible] INT 2Fh Function 1208h
See Also: AH = 120Bh

INT 2Fh Function 1208h — DOS 3+
DECREMENT SFT REFERENCE COUNT

[illegible] to the given System File Table by one

Call With
AX 1208h
DS:DI pointer to SFT
Returns
AX value of reference count before decrement
Note [illegible]

[illegible]

[illegible] See Chapter
If the SFT's reference count can now be [illegible] by hand

INT 2Fh Function 1209h — DOS 3+
FLUSH AND FREE DISK BUFFER

[illegible]

Call With
AX 1209h
DS:DI pointer to [illegible]

Note: [illegible] can only be called from within a DOS function call
See Also: AH = 1208h, AH = 121Eh

INT 2Fh Function 120Ah — DOS 3+
PERFORM CRITICAL ERROR INTERRUPT

[illegible]

SDA

Call With
AX 120Ah
DS DOS CS
SS DOS CS
Stack WORD extended error code
Returns
AL user response (0 = ignore, 1
CF error if retry, set
AX & stack changed
Notes [illegible]
SDA to set up the registers for the INT 24h
The code for this call reportedly sets the current DPB's first root directory sector to 1

Used by network redirectors such as MSCDEX
See Also: INT 2Ah

INT 2Fh Function 120Bh — DOS 3+
SIGNAL SHARING VIOLATION TO USER

Produces a critical error if an attempt was made to open a file that conflicts with the current sharing mode with inheritance allowed

Call With
- AX 120Bh
- ES:DI pointer to system file table entry for previously open of file
- STACK WORD extended error code (should be 20h = sharing violation)

Returns
- CF clear if operation should be retried
- CF set if operation should not be retried
  - AX error code (20h) see *21-59h*
- STACK unchanged

Note: This function can only be called during a DOS function call. It should only be called if an attempt was made to open an already open file in violation of the sharing rules

INT 2Fh Function 120Ch — DOS 3+
OPEN DEVICE AND SET SFT OWNER

Invokes the "device open" call on the device driver for the given SFT and then sets the owner of the last accessed FCB file to the calling process's PID

Call With
- AX 120Ch
- SDA current SFT pointer pointer to SFT for file
- DS DOS DS
- SS DOS DS

Returns
- ES, DI, AX destroyed (ES:DI may point to the SFT)

Note: Network redirectors must call this function for FCB operations (see *21-29h*)

INT 2Fh Function 120Dh — DOS 3+
GET DATE AND TIME

Return the current date and time in directory format

Call With
- AX 120Dh
- SS DOS DS

Returns
- AX current date in packed format see *21-2Ah*
- DX current time in packed format see *21-2Ch*

See Also: *21-2Ah, 21-2Ch*

INT 2Fh Function 120Eh — DOS 3+
MARK ALL DISK BUFFERS UNREFERENCED

Clears the "referenced" flag for all disk buffers. This flag is automatically set when a buffer is read or written and is used by the buffer management algorithm. Unreferenced buffers are generally replaced before referenced buffers

Call With
AX 120Eh
SS DOS DS
Returns
DS:DI pointer to first disk buffer
Notes
AX 1223h SHARE.NO-DELAY
See Also 21 1209h, 21 1210h

INT 2Fh Function 120Fh — DOS 3+
MAKE BUFFER MOST RECENTLY USED

Call With
AX 120Fh
DS:DI pointer to disk buffer
SS DOS DS
Returns
DS:DI pointer to next buffer in buffer list
Notes
Buffer's chained data is marked unused
See Also 21 1207h

INT 2Fh Function 1210h — DOS 3+
FIND UNREFERENCED DISK BUFFER

first use of the last "Mark Disk Buffers Unreferenced" call
Call With
AX 1210h
DS:DI pointer to first disk buffer to check
Returns
ZF clear if found
DS:DI pointer to first unreferenced disk buffer
ZF set if not found
Notes
AX 1223h SHARE.NO-DELAY
See Also 21 1201

INT 2Fh Function 1211h — DOS 3+
NORMALIZE ASCIZ FILENAME

Call With
CL 21
pointer to ASCIZ
DS:SI pointer to buffer for normalized filename
Returns
buffer filled
See Also 2Fh 2F 1221h

INT 2Fh Function 1212h — DOS 3+
GET LENGTH OF ASCIZ STRING

Returns the length of an ASCIZ-terminated character string.

Call With
- AX — 1212h
- ES:DI — pointer to ASCIZ string

Returns
- CX — length of string

See Also: INT 2Fh/1225h

INT 2Fh Function 1213h — DOS 3+
UPPERCASE CHARACTER

Returns the uppercase equivalent of a lowercase character. If the character is not lowercase, the character is unchanged.

Call With
- AX — 1213h
- STACK — WORD character to convert to uppercase

Returns
- AL — uppercase character
- STACK — unchanged

INT 2Fh Function 1214h — DOS 3+
COMPARE FAR POINTERS

Determines whether two FAR pointers point to the same location.

Call With
- AX — 1214h
- DS:SI — first pointer
- ES:DI — second pointer

Returns
- ZF set if pointers are equal, ZF clear if not equal

INT 2Fh Function 1215h — DOS 3+
FLUSH BUFFER

Performs all buffered writes for specified disk, then marks all buffers for that disk as unused.

Call With
- AX — 1215h
- DS:DI — pointer to disk buffer
- SS — DOS DS
- STACK — WORD drives for which to skip buffer flushing
  - high byte = 0 if low byte contains specific drive number, or 1 if all buffers for a drive other than that given in low byte

Returns:
- STACK — unchanged

Note: This function can only be called from within a DOS function call

See Also: AH = 1209h

INT 2Fh Function 1216h — DOS 3+
GET ADDRESS OF SYSTEM FILE TABLE ENTRY

[illegible] function 1220h

Call With
AX 1216h
BX system file table entry number such as returned from 2F 1220
Returns
CF clear if success
ES:DI pointer to system file table entry
CF set if BX greater than LASTDRIVE
Note for the implementation of this function see Figure 6.22
See Also 2F 1220

INT 2Fh Function 1217h — DOS 3+
GET CURRENT DIRECTORY STRUCTURE FOR DRIVE

Call With
AX 1217
SS DOS DS
STACK WORD drive 0 A 1 B etc
Returns
CF set on error
drive LASTDRIVE
CF clear if successful
DS:SI pointer to current directory structure for specified drive
STACK cleared
Note for implementation see Figure 6.1
See Also 2F 1219

INT 2Fh Function 1218h — DOS 3+
GET CALLER'S REGISTERS

Returns a pointer to the stack frame containing the INT 21h caller's registers

Call With
AX 1218
Returns
DS:SI pointer to saved caller's AX BX CX DX SI DI BP DS ES on stack
Note This function is only available within a DOS function [illegible]

INT 2Fh Function 1219h — DOS 3+
SET DRIVE

Call With
AX 1219
SS DOS DS
STACK WORD drive 0 drive 1 A etc
Returns
STACK [illegible]
Notes [illegible] only [illegible] for [illegible] DOS versions [illegible] 3.x [illegible] 4.x
Intercepting it inside a server call 21 5D00h
See Also 2F 1217h 2F 121Bh

INT 2Fh Function 121Ah — DOS 3+
GET FILE'S DRIVE

Determine which drive a filename specifies

Call With
- AX 121Ah
- DS:SI pointer to filename

Returns
- AL drive (0=default, 1=A:, etc.) FFh if invalid
- DS:SI pointer to filename without drive/leading \ if present

Note: Increments SI by 2 if name starts with drive letter followed by colon
See Also: 21/60h

INT 2Fh Function 121Bh — DOS 3+
SET YEAR/LENGTH OF FEBRUARY

Specify the current year and return the length of February for that year to allow storage that length internally

Call With
- AX 121Bh
- CL year - 1980
- DS DOS data segment

Returns
- AL number of days in February

See Also: *21/28h*

INT 2Fh Function 121Ch — DOS 3+
CHECKSUM MEMORY

Compute a checksum of the given range of memory. This function is also used by DOS to determining the day count since 1/1/1980 given a date

Call With
- AX 121Ch
- DS:SI pointer to start of memory to checksum
- CX number of bytes
- DX initial checksum
- SS DOS DS

Returns
- AX, CX destroyed
- DX checksum
- DS:SI pointer to first byte after checksummed range

See Also: 21/121Dh

INT 2Fh Function 121Dh — DOS 3+
SUM MEMORY

Add up the values in a range of bytes until the specified limit is exceeded and return the value which caused the limit to be exceeded. This function is also used by DOS to determine the year and month given a day count since 1/1/1980

Call With
- AX 121Dh
- DS:SI pointer to memory to add up
- CX 0000h

DX limit

Returns

AL byte which exceeded limit

CX number of bytes before limit exceeded

DX remainder after adding first CX bytes

DS:SI pointer to byte beyond the one which exceeded the limit

See Also: 21h,214Ch

INT 2Fh Function 121Eh — DOS 3+
COMPARE FILENAMES

Call With

AX 121Eh

DS:SI pointer to first ASCIIZ filename

ES:DI pointer to second ASCIIZ filename

Returns

ZF set if filenames equivalent, ZF clear if not

See Also: 21h,211Bh, 21h,221Bh

INT 2Fh Function 121Fh — DOS 3+
BUILD CURRENT DIRECTORY STRUCTURE

storage in which it was built

Call With

AX 121Fh

SS DOS DS

STACK WORD drive ltr

Returns

STACK trashed

INT 2Fh Function 1220h — DOS 3+
GET JOB FILE TABLE ENTRY

Call With

1220h

Returns

CF

AL file handle

CF clear if success

ES:DI pointer to JFT entry for file handle in current process

Note The byte pointed at by ES:DI contains the number of the SFT entry for the file handle, or 0FFh if the handle is not open.

For the implementation of this function, see Figure 6-22.

See Also

INT 2Fh Function 1221h — DOS 3+
CANONICALIZE FILE NAME

Convert ASCIIZ specification to return an absolute pathname which takes into account all remapping due to JOIN, SUBST, ASSIGN, or network redirections

Call With
- AX 1221h
- DS:SI pointer to file name to be fully qualified
- ES:DI pointer to 128 byte buffer for returning canonical file name
- SS DOS DS

Returns:
- see 21/60h

Note: This function can only be called from within a DOS function call and is otherwise identical to 21/60h

See Also: 21/60h, 2F/1123h

INT 2Fh Function 1222h — DOS 3+
SET EXTENDED ERROR INFO

Convert a set of caller-provided records, set the error class, locus, and suggested action corresponding to the current extended error code

Call With
- AX 1222h
- SS DOS data segment
- SS:SI pointer to 4 byte records
  - BYTE error code, FFh = last record
  - BYTE error class, FFh = don't change
  - BYTE suggested action, FFh = don't change
  - BYTE error locus, FFh = don't change
- SDA error code set

Returns:
- SI destroyed
- SDA error class, error locus, and suggested action fields set

Note: This function can only be called from within a DOS function call

See Also: 21/59h, 2F/1221h

INT 2Fh Function 1223h — DOS 3+
CHECK IF CHARACTER DEVICE

Determine whether the given name is the name of a character device

Call With
- AX 1223h
- DS DOS data segment
- SS DOS data segment
- SDA+218h (DOS 3.1-3.3) eight character blank-padded name
- SDA+22Bh (DOS 4.0-5.0) eight character blank-padded name

Returns:
- CF set if no character device by that name found
- CF clear if found
  - BH low byte of device attribute word

Note: This function can only be called from within a DOS function call

See Also: 21/5D06h, 21/5D0Bh

INT 2Fh Function 1224h — DOS 3+
SHARING DELAY

Call With
AX 1224h
SS DOS DS
Returns
[illegible] set by 21 4408 unless in server call (21 5D08)
[illegible]
See Also [illegible] 21 52

INT 2Fh Function 1225h — DOS 3+
GET LENGTH OF ASCIZ STRING

Return the length of a null-terminated ASCIZ string

Call With
AX 1225h
DS:SI pointer to ASCIZ string
Returns
CX length of string
See Also 21 1213h

INT 2Fh Function 1226h — DOS 3.3+
OPEN FILE

[illegible]

Call With
AX 1226h
CL access mode (AL from 21 3D)
DS:DX pointer to ASCIZ file
SS DOS DS if unknown

Returns

[illegible]
CF Error
AX
Notes
21 4B00
[illegible]
See Also

INT 2Fh Function 1227h — DOS 3.3+
CLOSE FILE

Close a previously opened file given its handle

Call With
AX [illegible]
BX file handle
SS DOS data segment

Returns

CF set on error
AL 06h invalid file handle
CF clear if successful

Notes: This function can only be called from within a DOS function call; it is otherwise equivalent to 21/3Fh

This function is used by NLSFUNC to access COUNTRY.SYS when invoked by the DOS kernel

See Also: *21/3Fh*, *21/1106h*, *21/1201*, *21/1226h*

INT 2Fh Function 1228h — DOS 3.3+
MOVE FILE POINTER

Set the current position in the given file

Call With

AX 1228h
BP 4200h, 4201h, 4202h, see *21/42h*
BX file handle
CX:DX offset in bytes
SS DOS DS

Returns:

as for 21/42h

Notes: This function is equivalent to 21/42h, but can be called from inside a DOS function call

The user stack frame pointer is set to data in the BP register, and AX is POPped prior to the POPF; thus, the flags are returned as set by the function, and finally the frame pointer is restored

This function is used by NLSFUNC to access COUNTRY.SYS when invoked by the DOS kernel

See Also: *21/42h*

INT 2Fh Function 1229h — DOS 3.3+
READ FROM FILE

Read data from a previously opened file

Call With

AX 1229h
BX file handle
CX number of bytes to read
DS:DX pointer to buffer
SS DOS DS

Returns

as for 21/3Fh

Note: This function is identical to 21/3Fh, but can only be called from within a DOS function call

This function is used by NLSFUNC to access COUNTRY.SYS when invoked by the DOS kernel

See Also: *21/3Fh*, *21/1226h*

INT 2Fh Function 122Ah — DOS 3.3+
SET FASTOPEN ENTRY POINT

Specify the addresses of the handlers for the FASTOPEN file name cache

Call With
AX 1224h
BX entry point to set: 0001h or 0002h
[illegible]

Returns
[illegible]

Notes: The entry point number [illegible] ored under DOS 3.30
[illegible] entry points are set [illegible] ected by the DOS 4.01 FASTOPEN

DOS 3.30+ FASTOPEN is called with:
AH *01h (unused)*
CX *appears to be offset*
DI *appears to be offset*
SI offset in IBMDOS of filename
AL *02h (unused)*
AH *03h (unused)*
SI offset in IBMDOS of filename
AL *00h (unused)*
AH subfunction: 00h, 01h, 02h
ES:DI *pointer to unknown item*
CX *unknown (with AL=01h and 02h only)*

Returns
CF set on error or not installed

Notes: [illegible] VSHDOS [illegible] FASTOPEN called with additional unknown arguments

---

INT 2Fh Function 122Bh — DOS 3.3+
IOCTL

Execute an IOCTL control function from within the network redirector

Call With
[illegible]
AH 12h (XMS from 21:44h)
SS:SP IBMDOS DS
additional registers as appropriate for 21:44xxh

Returns
as 21:44h

Notes: [illegible] the IOCTL call specified
[illegible] AX the IOCTL call specified and finally the frame pointer restored
[illegible] CLOSE, READ, WRITE, [illegible] the IBMDOS ke[illegible]

INT 2Fh Function 122Ch — DOS 3.3+
GET DEVICE CHAIN

Returns
[illegible]

Call With
[illegible]

Returns
[illegible] NUL [illegible]

See Also: 21:52h

INT 2Fh Function 122Dh — DOS 3.3+
GET EXTENDED ERROR CODE

Return the current extended error code

Call With
AX 122Dh
Returns:
AX current extended error code
See Also: *21/59h*, 2F/1222h

INT 2Fh Function 122Eh — DOS 4+
GET OR SET ERROR TABLE ADDRESSES

Specify or determine the locations of various tables used to convert error numbers into error messages

Call With
AX 122Eh
DL subfunction
- 00h get standard DOS error table (errors 00h-12h,50h-58h)
  - **Returns:**
    - ES:DI pointer to error table
- 01h set standard DOS error table
  - ES:DI pointer to error table
- 02h get parameter error table (errors 00h-0Ah)
  - **Returns:**
    - ES:DI pointer to error table
- 03h set parameter error table
  - ES:DI pointer to error table
- 04h get critical SHARE error table (errors 13h-21h)
  - **Returns:**
    - ES:DI pointer to error table
- 05h set critical SHARE error table
  - ES:DI pointer to error table
- *06h get unknown error table*
  - **Returns:**
    - ES:DI pointer to error table or 0000h:0000h
- *07h set unknown error table*
  - ES:DI pointer to error table
- 08h get error message retriever (see below)
  - **Returns:**
    - ES:DI pointer to FAR procedure to fetch error message
- *09h set unknown error table*
  - ES:DI pointer to error table

Notes: If the returned segment on a "get" is 0001h, then the offset specifies the offset of the error message table within COMMAND.COM, and the procedure returned by DL=08h should be called.
DOS 5.0 COMMAND.COM does not allow setting any of the addresses; they are always returned with segment 0001h
See Also: *21/59h*, 2F/0500h

Format of DOS 4.x error table

Offset	Size	Description
00h	BYTE	FFh
01h	2 BYTEs	offset of DOS 2.x
03h	BYTE	number of error headers following
04h	2N WORDs	table of all error headers for table

Offset	Size	Description
00h	WORD	error message number
02h	WORD	offset of error message from start of header

[illegible] ASCIZ count byte followed by msg

Note: [illegible] INT 21 [illegible]
offset of ASCIZ end of string, 0000h if invalid error number

Call error retrieval function with

[illegible]

Returns:
ES:DI pointer to error message command string

Note: [illegible] INT 21 [illegible]
[illegible]

Bugs: not yet tested for this function

This function is supported by DR DOS 5.0

INT 2Fh Function 122Fh — DOS 4.x only
SET DOS VERSION NUMBER TO RETURN

[illegible] DOS Version call
21 30h

Call With:
AX 1221h
DX DOS version number, 0000h to restore true DOS version

Note: [illegible]

See Also: 21 30h

INT 2Fh Function 13h — DOS 3.2+
SET DISK INTERRUPT HANDLER

Specify the address of the handler for most DOS disk access and return [illegible] address

Call With:
AH 13h
DS:DX pointer to interrupt handler disk driver calls on read/write
ES:BX address to restore INT 13h to on system halt, exit from root shell, or warm boot INT 19h

Returns:
DS:DX from previous invocation of this function
ES:BX from previous [illegible] this function

Notes: [illegible] INT 13h [illegible]
[illegible]

IBM's ROM BIOS

Before the first call to INT 2Fh, set the original BIOS INT 13h DS:DX and pointer to the previous IO.SYS INT 13h handler. Special Function for Hard Disk reads or writes with a code byte. If the original BIOS data (if IO.SYS) or the original INT 13h instruction (if IO.SYS) points at the specified sector

Most DOS 5+ Disk access goes through a call to DS:DX (the original INT 13h instructions) and invoked via an INT 13h instruction

This function presents a serious security loophole for any virus monitoring software which does not trap this call. Some Bulgarian viruses are known to use it to get the original BOOT entry points

For details of Int 2Fh function 21 see Ralf Brown's Chapter *DOS Interrupts*

See Also: *INT 13 AH 03h, INT 19h*

INT 2Fh Function 1400h — DOS 3.3+

NLSFUNC.COM - INSTALLATION CHECK

Determine whether NLSFUNC has been loaded

Called With

AX 1400h

Returns

AL 00h not installed, OK to install
01h not installed, not OK
FFh installed

Notes: Undocumented function, DOS 3+, supported by DR DOS 5.0, 6.0, Novell DOS 7, PTS-DOS 6.51+, S/DOS 1.0+, and Windows NT DOS box. Under DR DOS and Windows NT, DOSMGR.SYS sets this function to indicate that NLSFUNC is not required

Undocumented function, exists in MS DOS 3.3 but is not documented in prior versions

---

INT 2Fh Function 1400h — European MS DOS 4.0

POPUP "CheckPu" INSTALLATION CHECK

Determine whether POPUP is already memory resident. The POPUP interface is supplied with European MS DOS 4.0, and is required by NLSFUNC.EXE. Also for MS DOS 5.0 and above. DOS versions released after European MS DOS 4.01

Call With

AX 1400h

Returns:

AX FFFFh if installed
nX [illegible]
CF clear if successful
CF set on error
AX error code
0002h invalid function
0004h [illegible]

Note: [illegible] undocumented, program uses INT 21 8800 [illegible]

See Also: 21 1401h, 21 1402h, 21 1403h

INT 2Fh Function 1401h — DOS 3.3+

NLSFUNC.COM CHANGE CODE PAGE

Select a new code page as the default

Called With

AX 1401h

DS:SI pointer to internal code page structure, see below
BX new code page
DX country
Returns:
AL status
00h successful
else DOS error code
Note: This function is called by the DOS 3.3+ function Int 21 38
See Also: 21 6600

Format of DOS 3.30 internal code page structure

Offset	Size	Description
	WORD	
	WORD	number of supported
	n BYTEs	
	5 BYTEs	
	n BYTEs	
	n BYTEs	
00h	41 BYTEs	

INT 2Fh Function 1401h — European MS-DOS 4.0

POPUP PostPu OPEN/CLOSE POPUP SCREEN

Request access to the display from a background program
Call With:
AX 1401h
DL function: 00h open, 01h close
DH wait flag:
00h block until screen opens
01h return error if screen is not available
02h urgent, always open screen immediately
Returns:
CF clear if successful
BX amount of memory needed to save screen and keyboard info
0000h default save location can be used, only if DH was 02h
CF set on error
Note: The application has the screen to itself until the popup screen is closed
SeeAlso: 21 1400h

INT 2Fh Function 1402h — DOS 3.3+

NLSFUNC.COM GET COUNTRY INFO

Called With:
AX 1402h
BP subfunction, same as AL for 21 65h
BX code page
DX country code
DS:SI pointer to internal code page structure, see 2F 1401h
ES:DI pointer to user buffer
CX size of user buffer

Returns:
AL status
00h successful
else DOS error code
Notes: [illegible] DOS 3.3 [illegible] 21 05
[illegible] COUNTRY.SYS [illegible]
See Also: 21 05h 2F 1403h 2F 1404h

INT 2Fh Function 1402h — European MS-DOS 4.0
POPUP "SavePu" SAVE POPUP SCREEN

Make a copy of the background program's screen so that it can be restored later when the background program writes to the screen

Call With
AX 1402h
ES:DI [illegible] 0000:0000h to 0000:0006h [illegible] POPUP
Returns
CF clear if successful
CF set on error
AX error code
0001h process does not own screen
0004h unknown error
0005h invalid pointer
See Also: AX 1400h 2F 1401h,2F 1403h

INT 2Fh Function 1403h — DOS 3.3+
NLSFUNC.COM SET COUNTRY INFO

Select a new country code as the default

Called With
AX 1403h
[illegible] [illegible] AX 1401
BX code page
DX country code
Returns:
AL status
Note: [illegible] DOS 3.3 [illegible] 38h
See Also: 21 38h 2F 1402h 2F 1404h

INT 2Fh Function 1403h — European MS-DOS 4.0
POPUP "RestorePu" RESTORE SCREEN

[illegible] 1 [illegible] POPUP [illegible] wrote on the screen. The POPUP interface in European MS-DOS 4.0 conflicts with the NLSFUNC [illegible] MS-DOS 3.3 [illegible] DOS [illegible] European MS-DOS 4.0

Call With:
AX 1403h
ES:DI pointer to buffer containing [illegible] screen
0000h:0000h for default buffer in POPUP
Returns
CF clear if successful

CF set on error
AX error code (see AX=1402h "POPUP")

See Also: 2F 1400h, 2F 1401h, 2F 1402h

INT 2Fh Function 1404h — DOS 3.3+
NLSFUNC.COM — GET COUNTRY INFO

[illegible]

Called With
- AX 1404h
- BX code page
- DX country code
- DS:SI pointer to internal code page structure (see 2F 1401h)
- ES:DI pointer to user buffer

Returns
- AL status

Notes: This function is called by the DOS 3.3+ function 21 38h [illegible] COUNTRY.SYS [illegible]

See Also: 21 38h, 2F 1402h, 2F 1403h

INT 2Fh Function 14FEh — DR DOS 5.0
NLSFUNC — GET EXTENDED COUNTRY INFORMATION

[illegible] information for a country other than the current [illegible]

Call With
- AX 14FEh
- BX code page (FFFFh global code page, see 21 6602h)
- DX country ID (FFFFh current country, see 21 38h)
- ES:DI pointer to country information buffer
- CL info ID
  - 01h get general internationalization info
  - 02h get pointer to uppercase table
  - 04h get pointer to filename uppercase table
  - 05h get pointer to filename terminator table
  - 06h get pointer to collating sequence table
  - 07h get pointer to Double-Byte Character Set table
  - set [illegible] to return error if not installed

Return
- CF clear if successful
  - DS:SI pointer to requested information
- CF set [illegible]

[illegible] 00h [illegible] CL [illegible]

The value of CL is not range checked by the DR DOS 5.0 NLSFUNC

See Also: AX 14FFh, 21 65h

Format of DR DOS COUNTRY.SYS file

Offset	Size	Description
00h	0 BYTEs	[illegible] padded with NULs
7Eh	WORD	signature EDC1h
80h	var	country pointer records

Offset	Size	Description
00h	WORD	country code (0000h if current country)
02h	WORD	code page
04h	*WORD*	*unknown (0000h)*
06h	7 WORDs	reserved (0000h) or data table for subfunctions 01h-07h
var	var	country information

INT 2Fh Function 14FFh — DR DOS 5.0
NLSFUNC PREPARE CODE PAGE

This function is called by the DR DOS kernel when setting the current code page, it passes a codepage specification request to cached device drivers supporting the generic IOCTL call

Call With
AX 14FFh
BX code page
Returns
AX *unknown*
ZF set if AX 0000h

Note DR DOS 5.0 NLSPATCH removes this call and AX 0001h at AL was 00h–11h, but does not care
See Also: AX=14FFh, 2F 4400h 2F 6602h

INT 2Fh Function 1500h — DOS 4.00 only
GRAPHICS.COM INSTALLATION CHECK

Determine whether GRAPHICS has been loaded

Call With
AX 1500h
Returns
AX FFFFh
ES:DI unknown pointer pointer to graphics data

Note [illegible] with the CD-ROM Extensions install check also 2F 1500
See Also: 2F AC00h

INT 2Fh Function 1603h — MS Windows/386
GET INSTANCE DATA

Determine how much data of a given process must be saved to separate copies for each task

Call With
AX 1603h
Returns
AX 5248h 'RH' if supported
DS:SI Windows/386 instance data (see below)

Notes: DOSMGR calls this function with AX 1603h BX 0015h to see if it is running under DOS versions prior to 5.0

Structure returned by INT 2F 1603h for use in saving/restoring DOSMGR's state in other DOSMGR's behavior and instancing in general
See Also: AX=1607h, BX=0015h

Format of Windows 386 instance data

Offset	Size	Description
		[illegible]
		[illegible] DOS v2x
		0000h if not applicable
04h	WORD	number of instance data entries (max 3)
06h		Array of instance data entries

Offset	Size	Description
00h	WORD	segment (0002h - DOS K
02h	WORD	
04h	WORD	

INT 2Fh Function 1607h — Windows 3.0+
WINDOWS ENHANCED MODE VXD CALLOUT

[illegible] Windows Device Block
[illegible]
[illegible]

[illegible] with the VxD. As indicated in the next entry, MS DOS 5.0 and higher itself uses this mechanism to communicate with the Windows DOSMGR VxD.

[illegible] API
[illegible]
[illegible]

[illegible] that the below VxDs are known (from their callouts) in Windows 3.1

0000h V86MMGR
0001h VMD [illegible] Mouse Driver
[illegible]
0015h DOSMGR [illegible] below
[illegible]
0031h Page file [illegible] source code provided with DDK

For more information on the V86MMGR, VMD, VNETBIOS, and DOSMGR callout interfaces, see the [illegible] on disk. The block Dev 100 callout is documented in the Windows DDK.

INT 2Fh Function 1607h — DOS 5+
MS WINDOWS DOSMGR VIRTUAL DEVICE API

[illegible] MS DOS

Call With
AX 1607
BX 0001h VxD [illegible] DOSMGR
CX function
0000h get VM instance processing
Return CX
0000h not instanced
[illegible] DOS 5.0 kernel error 0001h
[illegible] DOS v5.0
ES:BX pointer to patch table (see below)
0001h set patches in DOS
DX bit mask of patch
bit 0 enable critical sections
bit 1 NOP setting check [illegible] user ID

bit 2 turn 21 .3Fh on STDIN into polling loop
bit 3 trap stack fault in "SYSINIT" to WIN386
bit 4 BIOS patch to trap "Insert disk X" to WIN386
Returns:
AX B97C h
BX bit mask of patches applied
DX A2ABh
0002h remove patches in DOS ignored by DOS 5.0 kernel+
DX bit mask of patch requests (see function 0001h)
0003h get size of DOS data structures
DX bit mask of request (only one bit can be set)
bit 0 Current Directory Structure size
Returns:
if supported request
AX B97C h
CX size in bytes of requested structure
DX A2ABh
else
all registers preserved
0004h determine instanced data structures
Returns:
AX B97C h if supported
DX A2ABh if supported (DOS 5.0 kernel returns 0000h)
BX bit mask of instanced items
bit 0 CDS
bit 1 SFT
bit 2 device list
bit 3 DOS swappable data area
0005h get device driver size
ES segment of device driver
Returns:
DX:AX 0000h:0000h on error (not device driver segment)
DX:AX A2ABh:B97C h if successful
BX:CX size of device driver in bytes

Notes: DOSMGR (DOS Manager) will check whether the OEM DOS BIOS data has been instanced via this API and will not perform its own default instancing of the normal DOS/BIOS data if such an API is not supported. DOSMGR will also try to access instancing data through 21/1603h. These functions are supported by the DOS 5+ kernel. DOSMGR contains tables of instancing information for earlier versions of DOS.

See Geoff Chappell's book *DOS Internals* for additional discussions of DOSMGR's behavior and instancing in general. Also see Chapter 1 "NOTDOSMGR."

See Also: 21/, 1603h

Format of patch table:

Offset	Size	Description
00h	2 BYTEs	DOS version: major, minor
02h	WORD	offset in DOS data segment of "SAVEDS"
04h	WORD	offset in DOS data segment of "SAVEBX"
06h	WORD	offset in DOS data segment of InDOS flag
08h	WORD	offset in DOS data segment of User ID word
0Ah	WORD	offset in DOS data segment of "CritPatch" table

	WORD	DOS segment of DOS data segment or "UMB_HEAD", containing segment of last MCB in conventional memory

INT 2Fh Function 160Bh — Windows 3.1
WINDOWS TSR IDENTIFY

[illegible] DX=0 to check for INT 2F 160Bh. Microsoft does document that the function may [illegible] Microsoft Windows Version 3.1 and Digital Research the Microsoft Developer [illegible] DOS 3.1 DR-DOS 3.41 [illegible] INT 2F 160Bh. See Ralf Brown's INT 2F 160B and [illegible] on disk.

INT 2Fh Function 1684h — Windows 3.0+
GET VXD API ENTRY POINT

Microsoft [illegible] INT 2F 1684h is used by Windows Device Driver Kit [illegible] Windows applications to call Windows whenever a DOS program [illegible] DOS [illegible] INT 2F 1684h to get a set of routines to an API provided by an Enhanced mode virtual device drivers (VxDs).

[illegible] INT 2F 1684h [illegible] describes the APIs provided [illegible] VxD. A DOS Windows program uses the first VxD identified [illegible] INT 2F 1684h [illegible] INT 2F 1684h from a real mode DOS program [illegible] DOS [illegible] INT 2F 1684h from protected mode [illegible] DOS [illegible] protected mode [illegible] API exists and is available. Otherwise, 0 is returned. By looping [illegible] VxD IDs [illegible] determine which VxDs provide APIs [illegible] which mode. The following [illegible] known to provide APIs:

0003h	VPICD	Virtual PIC Device	V86, PM
0005h	VTD	Virtual Timer Device	V86, PM
0009h	Reboot	Ctrl-Alt-Del reinitialization	PM
000Ah	VDD	Virtual Display Device	PM
000Ch	VMD	Virtual Mouse Device	V86, PM
000Dh	VKD	Virtual Keyboard Device	PM
000Eh	VCD	Virtual COMM Device	PM
[illegible]	[illegible]OSVxD	DOS [illegible] DOS extender	V86
0017h	SHELL	KERNEL VxD interface	PM
0030h	LoadHi	memory manager	V86
0031h	WINDEBUG	low level debugging	PM
0021h	PageFile	demand paged swap device	PM
0442h	VTDAPI	Multimedia timer	PM

[illegible] VTDAPI. For more information on VxD APIs see Andrew [illegible] "Writing Virtual Device Drivers for Windows" [illegible] VxD API is described in the interrupt list on disk; see INT 2F 1684h which also provides a handy list of VxD IDs.

INT 2Fh Function 168Ah — DPMI
DPMI - GET VENDOR SPECIFIC API ENTRY POINT

[illegible] extensions to the DPMI, the DOS Protected Mode Interface. [illegible] extensions are not. The most important extension [illegible] MS-DOS [illegible] the Windows KERNEL to bypass DPMI services and [illegible] Descriptor Table (LDT). For more information, see Matt Pietrek, *Windows Internals*, chapter 1.

INT 2Fh Function 17h — Windows 2.0+
WINDOWS CLIPBOARD API FOR DOS PROGRAMS

Documented services 1700h–1710h provide access to Windows 3.0 Enhanced Mode Windows Clipboard. Applications running under DOS programs can use these services to exchange data with Microsoft Windows. Microsoft KnowledgeBase article. The services are

1700h	Identify WinOldAp Version
1701h	Open Clipboard
1702h	Empty Clipboard
1703h	Set Clipboard Data
1704h	Get Clipboard Data Size
1705h	Get Clipboard Data
1708h	Close Clipboard
1709h	Compact Clipboard
170Ah	Get Device Capabilities

For more information see the description of the DESQview API

INT 2Fh Function 1900h — DOS 4.x only
SHELLB.COM INSTALLATION CHECK

Determine whether SHELLB has been loaded

Call With
- AX 1900h

Returns
- AL 00h not installed
  FFh installed

INT 2Fh Function 1901h — DOS 4.x only
SHELLB.COM SHELLC.EXE INTERFACE

Inform SHELLB of SHELLC's address, and return the location of a workspace for SHELLC

Call With
- AX 1901h
- BL 00h if SHELLC transient
  01h if SHELLC resident
- DS:DX segment:offset of entry point for SHELLC.EXE

Returns
- DS:DX segment:offset of workspace for SHELLC.COM

Note: SHELLB.COM SHELLC.EXE are supplied with DOS 4.x only

INT 2Fh Function 1902h — DOS 4.x only
SHELLB.COM COMMAND.COM INTERFACE

Get the name of the COMMAND.COM command file to be loaded when reloading the transient portion of itself from the current batch file

Call With
- AX 1902h
- DS:SI segment:offset of ASCIIZ string containing the name of the COMMAND.COM file to be loaded, with the filename element uppercased
- DS:DX pointer to buffer for results

Returns
- AL 00h failed, other

[illegible] for INT 2Fh function 1902h to obtain address of [illegible] call to SHELLB
mand =
b= no more Program Start Commands available
AL FFh success, then
nemory as DS:[DX+1] forwards filled as
DX+1 BYTE count of bytes of PSC
DX+2 N BYTEs Program Start Command text
BYTE 0Dh terminator

Note: [illegible] command from a [illegible] SHELLB provides Program Start Commands from its workspace
[illegible] SHELLB [illegible]
[illegible] COMMAND.COM which causes loop back to [illegible]
[illegible] PSCs are still stacked ups for subsequent execution

INT 2Fh Function 1903h — DOS 4.x only
SHELLB.COM COMMAND.COM INTERFACE

[illegible] the current batch file

Call With
AX 1903h
ES:DI pointer to ASCIZ batch file name as for 2F 1902h
Returns
AX [illegible]
AL 00h if it does not

INT 2Fh Function 1904h — DOS 4.x only
SHELLB.COM SHELLB TRANSIENT TO TSR Interface

[illegible] DOS 5 and later

Call With
AX 1904h
Returns
ES:DI pointer to name of current shell batch file
WORD number of bytes of name following
BYTEs ASCIZ name of shell batch file

INT 2Fh Function 1A00h — DOS 4+
ANSI.SYS INSTALLATION CHECK

Determine whether ANSI.SYS is present

Call With
AX 1A00h
Returns
AL FFh if installed

Note: [illegible] DOS 5 and later is undocumented for DOS 4.x

INT 2Fh Function 1A01h — DOS 4+
ANSI.SYS GET/SET DISPLAY INFORMATION

[illegible] DOS IOCTL interface to ANSI.SYS

Call With
AX 1A01h
CL function
00h (or SET)
01h (or GET)
DS:DX [illegible]
Returns:
CF set on error
AX error code (may not standard)
CF clear if successful
AX destroyed
See Also: INT 2Fh AX=4401h & 2Fh AX=1A02h

INT 2Fh Function 1A02h — DOS 4+
ANSI.SYS MISCELLANEOUS REQUESTS

Get or set miscellaneous ANSI.SYS flags

Call With
AX 1A02h
DS:DX pointer to parameter block (see below)
Note: DOS 5+ chains to the previous handler if AL > 02h
See Also: INT 2Fh AX=1A01h

Format of parameter block

Offset	Size	Description
00h	BYTE	subfunction 00h set reset interlock 01h get (CF clear)
01h	BYTE	interlock state 00h reset, 01h set [illegible] (ANSI.SYS [illegible]) must hook onto INT 10h AH=00h mode set
02h	BYTE	returned 00h if INT 2Fh not in effect 01h if INT 2Fh in effect

INT 2Fh Function 1B00h — DOS 4+
XMAEMS.SYS INSTALLATION CHECK

Determine whether XMA2EMS.SYS has been loaded

Call With
AX 1B00h
Returns
AL FFh if installed
Note: [illegible] XMA2EMS.SYS [illegible] DOS [illegible] times to hide. This extension hooks onto INT 67h AH [illegible] being used by DOS
See Also: INT 2Fh AH=1Bh

INT 2Fh Function 1Bh — DOS 4+
XMAEMS.SYS GET HIDDEN FRAME INFORMATION

Determine [illegible] XMA2EMS tasks from real [illegible]

Call With
AH 1Bh
AL nonzero
DI hidden physical page [illegible]
Returns
AX FFFFh if hidden [illegible]
AX 0000h if OK, then
ES segment of page frame
DI physical page number
Notes [illegible] NLSFUNC [illegible] NLSFUNC will [illegible]
DOS
2 DOS OPEN makes this call with AL = FFh
See Also: 21 1400

INT 2Fh Function 2300h — DR DOS 5.0
GRAFTABL INSTALLATION CHECK

Determines whether the DR DOS GRAFTABL has been installed
Call With
AX 2300h
Returns
AH FFh
Note: This uses all zero checks rather than the usual format of returning AL = FFh if installed
See Also: INT 21 AH = 23h

INT 2Fh Function 23h — DR-DOS 5.0
GRAFTABL GET GRAPHICS DATA

Determines the location of the graphics data used by GRAFTABL
Call With
AH 23h
AL nonzero
Returns
AH FFh
ES:BX pointer to graphics data
See Also: 21 2400

INT 2Fh Function 43h — XMS
XMS 3.0 SERVICES

[illegible] XMS [illegible] XMS [illegible] used to find
it is not a device named [illegible] Microsoft has discretely placed an XMS30.EXE file on [illegible] Compuserve
forum. The new XMS 3.0 functions

88h Query any Free Extended Mem
89h Allocate any Extended Memory Block
8Eh Get Extended EMB Handle
8Fh Reallocate any Extended Memory

[illegible] 32 bit
[illegible] XMS specification since
[illegible] this was a prob
[illegible] XMB [illegible] Not Extended Memory
For more information see Microsoft's XMS30.EXE, or the interrupt list on disk

INT 2Fh Function 4601h — DOS 5+
KERNEL UNKNOWN FUNCTION

The purpose of this function has not been determined

Call With
AX 4601h
Returns:
[illegible]

Note: This function migrates the MCB following the caller's PSP memory block into the DOS data segment
See Also: INT 2Fh 4602h

INT 2Fh Function 4602h — DOS 5+
KERNEL UNKNOWN FUNCTION

The purpose of this function has not been determined

Call With
AX 4602h
Returns:
[illegible]

Note: [illegible] migrates [illegible] MCB [illegible] DOS [illegible] be Moved following caller's PSP memory block
See Also: INT 2Fh 4601h

INT 2Fh Function 4A00h — DOS 5+
SINGLE FLOPPY LOGICAL DRIVE CHANGE NOTIFICATION

[illegible] assigned to the only floppy drive [illegible] [illegible] [illegible] [illegible]

Called With
AX 4A00h
CX 0000h
DH new drive number
DL current drive number
Returns:
CX FFFFh to skip "Insert diskette for drive X:" message
Note: [illegible] displaying the message "Insert diskette for drive X: [illegible]

INT 2Fh Function 4A01h — DOS 5+
QUERY FREE HMA SPACE

[illegible]

Call With
AX 4A01h
Returns:
BX number of bytes [illegible] HMA [illegible] DOS [illegible] HMA
[illegible] HMA [illegible] [illegible] [illegible] HMA

Note: This function is called by Windows 3.1 DOSX.EXE [illegible] DOS OSX [illegible] the March 1993 *Microsoft Systems Journal*
See Also: INT 2Fh 4A02h

INT 2Fh Function 4A02h — DOS 5.0
ALLOCATE HMA SPACE

Request a section of the High Memory Area for storing a portion of the TSR's code or data

Call With
AX 4A02h
BX number of bytes

Returns
ES:DI pointer to start of allocated HMA block or FFFFh:FFFFh

Changes

DOS version

Notes that causes DOS is loaded in the HMA. DOS=HIGH in CONFIG.SYS
This function is called by Windows' SYSTEM.EXE
There is no corresponding call to deallocate HMA space

See Also: 21 4A03h

INT 2Fh Function 4A05h — DOS 5+
DOSSHELL TASK SWITCHING API

DOSSHELL

Call With
AX 4A05h
SI function
subfn 0
other reserved

Notes

See Also: INT *xBIOS*

INT 2Fh Function 4A06h — DOS 5+
ADJUST MEMORY SIZE

DOS

Called With
AX 4A06h
DX segment following the last byte of conventional memory

Returns
DX segment following the last byte of memory available for use by DOS

Notes

INT 12h See Chapter *DOS Internals* Chapter 3
See Also: INT 27

INT 2Fh Function 4A10h Subfn 0000h — SMARTDRV v4+
Smartdrv Installation Check And Hit Ratios

stable and flow effective

delete listing on disk under 21 440Eh

Call With
AX 4A10h
BX 0000h
CX FABAh (v4.1+ see Note)
Returns
AX BABEh if installed
DX:BX cache hits
DI:SI cache misses
BP version (400 = 0400h)
CX *unknown*
Notes: Microsoft's SMARTDRV API included in the cache supports the PC Cache v8.0
+ DBSPACE.BIN is not in the DOS SMARTDRV.EXE nor does it check in advance (like CX=FABAh or AX=4A00h) for DBSPACE.BIN. Instead, it issues a critical error message. Common use of SMARTDRV v4.0 with DoubleSpace" and aborts the caller with 21 4C00h
See Also AX=4A00h BX=0001h AX=4A10h BX=0003h AX=4A10h BX=0004h AX=4A10h BX=0005h AX=4A10h BX=0007h AX=4A10h BX=1234h 2F 4402h "SMARTDRV" 2F 4403h "SMARTDRV"

INT 2Fh Function 4A10h Subfn 0001h — SMARTDRV v4+
RESET CACHE

Call With
AX 4A10h
BX 0001h
Returns:
registers unchanged

Note: this function is also supported by PC Cache v8.0
See Also: AX=4A10h BX 0000h AX=4A10h BX 0002h

INT 2Fh Function 4A10h Subfn 0002h — SMARTDRV v4+
FLUSH BUFFERS

Force all modified data to be written to disk immediately
Call With
AX 4A10h
BX 0002h
Returns
registers unchanged
Note: this function is also supported by PC Cache v8.0
See Also: AX=4A10h BX 0000h AX=4A10h BX=0001h

INT 2Fh Function 4A10h Subfn 0003h — SMARTDRV v4+
STATUS

Determine the caching status of a specified drive

Call With
AX 4A10h
BX 0003h
BP drive # (0=A, 1=B, etc.)
DL subfunction
[illegible]
01h turn on read cache

03h turn on write cache
04h turn off write cache
Returns
AX BARRIER OK
DL FFh if drive does not exist

cached
write-through

0=A 1=B
Note
Multiple calls are allowed
This function is also supported by PC Cache v8.0
See Also AX=4A10h, BX=0000h

INT 2Fh Function 4A10h Subfn 0004h — SMARTDRV v4+
GET CACHE SIZE

DOS 5+
Call With
AX 4A10h
BX 0004h
Returns
AX cache size in bytes
BX largest number of elements
CX size of elements in bx
DX number of elements under Windows
Note This function is also supported by PC Cache v8.0
See Also AX=4A10h, BX=0000h, AX=4A10h, BX=0005h

INT 2Fh Function 4A10h Subfn 0005h — SMARTDRV v4+
GET DOUBLE BUFFER STATUS

Determine whether the double-buffering code was
Call With
AX 4A10h
BX 0005h
DL drive # 0=A 1=B
Returns
AX BARRIER OK, buffer
DX if
See A

INT 2Fh Function 4A10h Subfn 0006h — SMARTDRV v4+
CHECK IF DRIVE CACHEABLE

SMARTDRV calls this
at startup to determine whether it should cache a particular drive
Called with
AX 4A10h
BX 0006h
CL drive number 01h = A

Returns:
AX 0000h if drive should not be cached by SMARTDRV
See Also: AX=4A10h BX=0000h

INT 2Fh Function 4A10h Subfn 0007h — SMARTDRV v4+
GET DEVICE DRIVER FOR DRIVE

Determines the device driver for the specified drive

Call With:
AX 4A10h
BX 0007h
BP drive number

Returns:
DI unknown
ES:DI pointer to device driver header for drive

Note: This function is also supported by PC Cache v3.0
See Also: AX=4A10h BX=0000h

INT 2Fh Function 4A10h Subfn 000Ah — SMARTDRV v4+
GET UNKNOWN TABLE POINTER

The purpose of this function has not yet been determined

Call With:
AX 4A10h
BX 000Ah

Returns:
ES:AX [illegible] pointer to table containing info; see below

Note: This function is also supported by PC Cache v3.0
See Also: AX=4A10h BX=0000h

Format of data table

Offset	Size	Description
00h	*8 BYTEs*	*unknown*
08	WORD	[illegible]

INT 2Fh Function 4A10h Subfn 1234h — SMARTDRV v4+
SIGNAL SERIOUS ERROR

The [illegible]

Call With:
AX 4A10h
BX 1234h

Note: This function is also supported by PC Cache v3.0
See Also: AX=4A10h BX=0000h

INT 2Fh Function 4A11h Subfunc FFFEh — DBLSPACE.BIN
RELOCATE

Move the DBLSPACE.BIN driver to its final location in memory

Call With:
AX = 4A11h
BX = FFFEh
ES = segment to which to relocate DBLSPACE.BIN

Returns

[illegible]

Other DoubleSpace API calls include functions 3 and 4, which at one point were "reserved
[illegible] are documented in Microsoft's *MS-DOS 6.0 Programmer's Reference*
See Also: AX=4A11h BX=1111

INT 2Fh Function 4A11h Subfunc FFFFh — DBLSPACE.BIN
GET RELOCATION SIZE

[illegible] of the DBLSPACE.BIN driver requires

Call With
AX=4A11h
BX=FFFF
Returns
AX=[illegible] paragraphs needed by DBLSPACE.BIN
Note: [illegible]

See Also: AX=4A11h BX=0000h, AX=4A11h [illegible]

INT 2Fh Function 4A13h — DBLSPACE.BIN
GET UNKNOWN ENTRY POINTS

[illegible] the purpose of this call has not been determined
Call With
AX=4A13h
Returns
AX=13A3h if supported
ES:BX=pointer to entry point record, see below
See Also: AX=[illegible] BX=0000h

Format of entry point record

Offset	Size	Description
00h	DWORD	pointer to unknown FAR function
[illegible]	[illegible]	FAR JUMP instruction to unknown function

INT 2Fh Function 5500h — DOS 5+
COMMAND.COM INTERFACE

[illegible] COMMAND.COM
Int 2Fh AX=5500h primary COMMAND.COM returns this portion
Call With
AX=5500h
Returns
AX=0000h
DS:SI=pointer to entry point table
Note: [illegible] COMMAND's secondary portion, most assumes that [illegible] the resident portion is on the stack and are thus not

INT 2Fh Function 5600h — DOS 6+
INTERLNK Install Check

INTERLNK is Microsoft's device driver for allowing one computer [illegible]

INT 2Fh Function 9400h — Workgroup Connection
MICRO.EXE INSTALLATION CHECK

Determine whether the MICRO.EXE [illegible] Workgroup Connection is installed

Call With
    AX 9400h
Returns
    AL 07h or 08h if installed
Note: 2F:9401-9404 are also used, but their meaning is unknown
See Also [illegible] AX=9402h, AX=9403h, AX=[illegible] 21/AX=4400h, MICRO.EXE, NET.EXE

INT 2Fh Function AC00h — DOS 4.01+
GRAPHICS.COM INSTALLATION CHECK

Determine whether GRAPHICS has been loaded

Call With
    AX AC00h
Returns
    AX FFFFh
    [illegible]

Note: [illegible] that occurred in DOS 4.00
See Also: 21/AX=5000h

INT 2Fh Function AD00h — DOS 3.3+
DISPLAY.SYS INSTALLATION CHECK

Determine whether DISPLAY.SYS is present

Call With
    AX AD00h
Returns
    AL FFh if installed
    [illegible] 00h if MS-DOS 3.30 or DOS 4.01

Note: [illegible] listed here.

INT 2Fh Function AD01h — DOS 3.3+
DISPLAY.SYS INTERNAL SET ACTIVE CODE PAGE

Specify which code page DISPLAY.SYS should use

Call With
    AX AD01h
    BX new code page
Returns
    CF clear if successful

AX 0001h
CF set if error unsupported code page
AX 0000h
See Also: 21 AD02h

INT 2Fh Function AD02h — DOS 3.3+
DISPLAY.SYS INTERNAL - GET ACTIVE CODE PAGE

page DISPLAY.SYS is currently using

Call With:
AX AD02h
Returns:
BX FFFFh system has hardware code page
CF clear if successful
BX current code page
See Also: 21 AD01h, 21 AD03h

INT 2Fh Function AD03h — DOS 3.3+
DISPLAY.SYS INTERNAL - GET CODE PAGE INFORMATION

to receive information the number of code pages supported and the [illegible] with available code pages

Call With:
AX AD03h
ES:DI pointer to buffer for code page information, see below
CX size of buffer, in bytes
Returns:
CF set if [illegible]
CF clear if successful
ES:DI buffer filled
See Also: 21 AD01h, 21 AD05h

Format of DOS 5.0 code page information

Offset	Size	Description
00h	WORD	number of software code pages
02h	*WORD*	*unknown, 0000h*
04h	WORD	number of hardware code pages
06h	N WORDs	hardware code page numbers

[illegible]

INT 2Fh Function AD10h — DOS 4.x only
DISPLAY.SYS INTERNAL - INSTALLATION CHECK

[illegible] to see if DISPLAY.SYS is loaded; this subfunction for APPEND also returns the DISPLAY.SYS version

Call With:
AX AD10h
additional arguments if any: none
Returns:
AX FFFFh
BX unknown, 0100h if DOS 4.0

INT 2Fh Function AD10h — DOS 5.0
DISPLAY.SYS INTERNAL - UNKNOWN FUNCTION

The purpose of this function has not been determined

Call With
AX AD10h
additional arguments if any unknown
Returns
CF cleared if successful
CF set on error
Note This function is a NOP if the active code page has been locked via AD02h returns BX=FFFFh its purpose otherwise is not known

INT 2Fh Function AD40h — DOS 4+
UNKNOWN FUNCTION

The purpose of this function has not been determined

Call With
AX AD40h
DX *unknown*
additional arguments if any unknown
Returns
unknown
Note Undocumented DOS 4.0 PRINT.COM and DOS 5+ PRINT.EXE

INT 2Fh Function AD80h — DOS 3.3+
KEYB.COM INSTALLATION CHECK

Determine whether KEYB.COM has been loaded

Call With
AX AD80h
Returns
AL FFh if installed
BX version number (major in BH minor in BL)
ES:DI pointer to internal data (see below)
Notes MS-DOS 3.30 PC-DOS 3.31 MS-DOS 5.00 & 6.00 report version 3.30
Most of the data addressed by the pointer returned by DOS 3+ KEYB is undocumented and undocumented

Format of KEYB internal data:

Offset	Size	Description
00h	DWORD	original INT 09h
04h	DWORD	original INT 2Fh
08h	*6 BYTEs*	*unknown*
0Eh	WORD	[illegible]
10h	*BYTE*	[illegible]
11h	*BYTE*	[illegible]
12h	*4 BYTEs*	*unknown*
16h	2 BYTEs	country ID letters
18h	WORD	current code page
—DOS 3.3—		
1Ah	*DWORD*	*pointer to first font [illegible]*
1Eh	*DWORD*	*pointer to [illegible] code page [illegible]*

	2 BYTEs	*unknown*
	WORD	pointer to key translation data
	WORD	pointer to last item in code page table list (see below)

DOS 4.01+

	3 BYTEs	
	BYTE	
	WORD	
	3 BYTEs	
	WORD	pointer to key translation data
00h	WORD	pointer to last item in code page table list (see below)
02h	9 BYTEs	*unknown*

Format of code page table list entries

Offset	Size	Description
00h	WORD	pointer to next item (FFFFh if last)
	WORD	code page
	2 BYTEs	*unknown*

Format of translation data

Offset	Size	Description
00h	WORD	size of data in bytes (including this word)
	N - 2 BYTEs	*unknown*

INT 2Fh Function AD81h — DOS 3.3+
KEYB COM — SET KEYBOARD CODE PAGE

Select a new code page list to use by the keyboard

Call With
- AX = AD81h
- BX = code page (see *21 0601h*)

Returns
- CF set on error
  - AX = 0001h code page not available
- CF clear if success

Note: [illegible] DOS [illegible] but undocumented for earlier versions

See Also: *2F AD82h*

INT 2Fh Function AD82h — DOS 3.3+
KEYB COM — SET KEYBOARD MAPPING

Specify whether the keyboard driver should use the standard or the foreign key mappings

Call With
- AX = AD82h
- BL = new state
  - 00 = US keyboard, Control At E1

Returns
- CF set on error, AL = 01h or FFh
- CF clear if success

Note: This function has been [illegible] DOS 3.3 but was undocumented for earlier versions

See Also: *2F AD81h, 2F AD83h*

INT 2Fh Function AD83h — DOS 5+
KEYB COM - GET KEYBOARD MAPPING

Determine whether the keyboard driver is using the standard or Dvorak keyboard mapping

Call With
AX A083h

Returns
BL current state
00h US keyboard
FFh foreign keyboard

See Also: 2F AD82h

INT 2Fh Function AE00h — DOS 3.3+
INSTALLABLE COMMAND INSTALLATION CHECK

Determine whether an installable TSR extension to COMMAND.COM is present

Called With
AX AE00h
DX FFFFh
CH FFh first call 0 second call
CL length of command line tail 4DOS 4.0
DS:BX pointer to command line buffer see below
DS:SI pointer to command name buffer see below
DI 0000h 4DOS 4.0

Returns
AL [illegible] COMMAND.COM
AL 00h if the command should be executed as usual

Notes: This call provides [illegible] command.com [illegible] APPEND

See Also: INT 21h

Format of command line buffer

Offset	Size	Description
00h	BYTE	max length of command line as in 21 0Ah
01h	BYTE	[illegible]
	N BYTEs	command line text terminated by 0Dh

Format of command name buffer

Offset	Size	Description
00h	BYTE	length of command name
01h	N BYTEs	[illegible] 4DOS 4.0

INT 2Fh Function AE01h — DOS 3.3+
INSTALLABLE COMMAND EXECUTE

Execute a TSR extension to COMMAND.COM's set of internal commands. The extension may

Called With
AX AE01h
DX FFFFh

CH	00h
CL	length of command name (DOS 4+)
DS:SI	pointer to command name buffer (see 2F AE00h)
DS:BX	pointer to command line buffer (see 2F AE00h)

Returns
DS:SI buffer updated

[illegible]
to execute and the command line buffer contains the command's parameters; the first
DS:S[illegible] bytes are ignored
N[illegible] 2F AE00h indicated was
[illegible]
APPEND hooks this call

INT 2Fh Function B000h — DOS 3.3+
GRAFTABL.COM INSTALLATION CHECK

Determine whether GRAFTABL has been loaded
Call With

AX	B000h

Returns

AL	00h not installed, OK to install
	01h not installed, not OK to install
	FFh installed

Note [illegible] called by DISPLAY.SYS. It has bee[illegible] DOS [illegible]
[illegible]
See Also: 2F B001h

INT 2Fh Function B001h — DOS 3.3+
GRAFTABL.COM GET GRAPHICS FONT TABLE

Call With

AX	B001h
DS:BX	pointer to DWORD buffer for address of 8x8 [illegible]

Returns
buffer fixed
AL = FFh

Note [illegible] MS-DOS [illegible]
See Also: 2F B000h

INT 2Fh Function B700h — DOS 3.3+
APPEND INSTALLATION CHECK

Determine whether APPEND has been loaded

Call With

AX	B700h

Returns

AL	state
	00h not installed
	FFh installed

Note [illegible]
patible [illegible]
This function is documented for DOS 5.0

INT 2Fh Function B701h — APPEND GET APPEND PATH

DOS

Alternative to function B704h to retrieve the current list of directories in which APPEND will search for a file

Call With
AX B701h

Returns
ES:DI pointer to active APPEND path

Notes Not all versions of APPEND support this call; use AX=B704h first and only call this function if that one is not supported

MS-DOS 3.30 APPEND displays "Incorrect APPEND Version" and aborts the caller

See Also AX=B704h

INT 2Fh Function B702h — APPEND VERSION CHECK

DOS 3.3+

Determine which version of APPEND has been loaded

Call With
AX B702h

Returns
AX 0 if not DOS 4.0 APPEND, also 0 if DOS 5.0 APPEND
AL major version number
AH minor version number, otherwise

Note This function is documented for DOS 5.0

See Also AX=B71Ah

INT 2Fh Function B703h — APPEND HOOK INT 21h

DOS 3.3, 5.0

Specify the handler APPEND should use when it has installed its own INT 21h hook

Call With
AX B703h
ES:DI pointer to INT 21h handler APPEND should call prior to

Returns
CF 0
ES:DI pointer to APPEND's INT 21h handler

Note Each invocation of this function toggles a flag which APPEND uses to determine whether to chain to the user handler or the original INT 21h

INT 2Fh Function B704h — APPEND GET APPEND PATH

DOS 3.3+

Return the current APPEND path

Call With
AX B704h

Returns
ES:DI pointer to active APPEND path (128 bytes max)

Note This function is documented for DOS 5.0. Some versions of append do not support this call, and return AL=01h to indicate this case; you should call AX=B701h to get the APPEND path

See Also AX=B701h

INT 2Fh Function B706h — DOS 4+

APPEND — GET APPEND FUNCTION STATE

Determine which actions APPEND is performing

Call With
- AX = B706h

Returns
- BX = APPEND state
  - bit 0 set if APPEND active
  - bits 1-14 reserved
  - bit 15 (DOS 5.0) set if APPEND applies directory search even if a drive has been specified
  - bit 15 set if PATH flag active
  - bit 14 set if /E flag active (environment var APPEND exists)
  - bit 13 set if /X flag active

INT 2Fh Function B707h — DOS 4+

APPEND — SET APPEND FUNCTION STATE

Specify which actions APPEND should perform

Call With
- AX = B707h
- BX = APPEND state bits (see INT 2F/B706h)

INT 2Fh Function B710h — DOS 3.3+

APPEND — GET VERSION INFO

Determine which version of APPEND has been loaded

Call With
- AX = B710h

Returns
- AX = current APPEND version (see INT 2F/B706h)
- BX = [illegible]
- CX = [illegible]
- DL = major
- DH = minor

See Also: INT 2F/AE00h

INT 2Fh Function B711h — DOS 4+

APPEND — SET RETURN FOUND NAME STATE

Specify that the expanded pathname should be written over the filename passed to the next INT 21h call

Call With

[illegible]
- AX = B711h
- BL = [illegible]
  - 00h = [illegible]
  - 01h = [illegible]

INT 21 call processed by APPEND

BUG: DOS 4.0 APPEND reported as overwrites DS:DX instead of DS:SI for INT 21/AE00h

See Also: INT 41

INT 2Fh Function B800h — Network

INSTALLATION CHECK

Determine whether a network is [illegible]

Call With
AX B800h
Returns
AL status
00h not installed
nonzero installed
BX installed component flags (test in this order)
bit 0 server
bit 2 messenger
bit 1 receiver
bit 3 redirector

INT 2Fh Function B803h — Network
GET NETWORK EVENT POST HANDLER

This function is used in conjunction with 2F B804h to hook into the network event post routine

Call With
AX B803h
Returns
ES:BX pointer to event post handler (see 2F B804h)
See Also: 2F B804h, 2F B903h

INT 2Fh Function B804h — Network
SET NETWORK EVENT POST HANDLER

This function is used in conjunction with 2F B803h to hook into the network event post routine

Call With
AX B804h
ES:BX pointer to new event post handler
Note: DOS expects handler to call for all network events (but events are defined for message received and critical network error)
See Also: 2F B803h, 2F B904h

Values post routine is called with:
AX 0000h (mail slot message)
DS:SI pointer to ASCIIZ originator name
DS:DI pointer to ASCIIZ destination name
ES:BX pointer to text header (see below)
AX 0001h start multiple message block
CX block group ID
DS:SI pointer to ASCIIZ originator name
DS:DI pointer to ASCIIZ destination name
AX 0002h multiple block text
CX block group ID
ES:BX pointer to text header (see below)
AX 0003h end multiple block message
CX block group ID
AX 0004h message aborted due to error
CX block group ID
AX 0101h server request (all buffers formatted network request)
Returns:
AX FFFFh (PC LAN will process error)
AX 0102h (unexpected network error)

ES:BX pointer to NCB (see *INT 5C/6*)
AX 0103h (server received INT 24h error)
other registers as for INT 24h, except AH is no BEH
Returns
nothing (but sends 0808h and EEEBx and exits)
Returns
AX response code
0000h user post routine processed message
[illegible]
EEEBx LAN will process message

Format of text header

Offset	Size	Description
00h	WORD	length of text (maximum 512 bytes)
02h	N BYTEs	text of message

[illegible]

INT 2Fh Function B807h — Network
GET NetBIOS NAME NUMBER OF MACHINE NAME

Return the network machine number

Call With
AX B80
Return
NetBIOS name number of the machine name

See Also: *21 xx/08*

INT 2Fh Function B808h — Network
RELINK KEYBOARD HANDLER

[illegible]

Call With
AX B808
ES:BX pointer to INT 09 handler for RELINKED (should already point to INT 09h)

Note: Allows all requests that would normally go to the network software chain on an INT 09 without preventing calls to the previous handler to relink, but does not allow a new handler to be added such that the network [illegible]
INT 09h requests chain directly to the previous handler
See Also: *21 B808*

INT 2Fh Function B809h — Network
LANtastic NetWare Lite VERSION CHECK

Determine which version of the network software has been installed

Call With
AX B809
Returns
AH major version
AL minor version (decimal)

Note: See *21 5E* for the [illegible] Extended Network Control Block
NetWare 1994 for more on the NetWare Lite API

INT 2Fh Function B809h — Network PC

LAN Program, LAN Manager, DOS LAN Requester Version Check

Determine which version of the network software has been installed. Note that these networks return [illegible] in the way LANtastic and NetWare Lite return the version.

Call With
AX B809

Returns:
AH minor version (decimal)
AL major version

See Also: AX=4E53h AX=B800h

INT 2Fh Function B900h — PC Network

RECEIVER.COM INSTALLATION CHECK

Determine whether the PC Network receiver software has been installed

Call With
AX B900h

Returns:
AL 00h if not installed
FFh if installed

INT 2Fh Function B901h — PC Network

RECEIVER.COM GET RECEIVER.COM INT 2Fh HANDLER ADDRESS

Determine the entry point for the RECEIVER.COM INT 2Fh handler, which can be called directly by bypassing the DOS multiplex interrupt (INT 2Fh) and calling the RECEIVER.COM handler directly.

Call With
AX B901h

Returns
AL *unknown*
ES:BX pointer to RECEIVER.COM INT 2Fh handler

INT 2Fh Function B903h — PC Network

RECEIVER.COM GET RECEIVER.COM POST ADDRESS

[illegible] the address of the [illegible] POST handler [illegible]

Call With
AX B903h

Returns
ES:BX pointer to POST handler

See Also: 2F B803h, 2F B904h

INT 2Fh Function B904h — PC Network

RECEIVER.COM SET RECEIVER.COM POST ADDRESS

The RECEIVER.COM [illegible] INT 2F B903h to [illegible] POST handler [illegible]

Call With
AX B904h
ES:BX pointer to new POST handler

See Also: 2F B804h, 2F B905h

INT 2Fh Function B905h — PC Network
RECEIVER.COM — GET FILENAME

Returns the filenames used internally by RECEIVER.COM

Call With
- AX — B905h
- DS:BX — pointer to 128-byte buffer for filename 1
- DS:DX — pointer to 128-byte buffer for filename 2

Returns
- Buffers filled from RECEIVER.COM internal [illegible]

Notes [illegible]

See Also: 2F:B906h

INT 2Fh Function B906h — PC Network
RECEIVER.COM — SET FILENAME

Specifies the filenames which RECEIVER.COM uses internally

Call With
- AX — B906h
- DS:BX — pointer to 128-byte buffer for filename 1
- DS:DX — pointer to 128-byte buffer for filename 2

Returns
- RECEIVER.COM internal buffers filled from user buffers

Notes [illegible]

See Also: 2F:B905h

INT 2Fh Function B908h — PC Network
RECEIVER.COM — UNLINK KEYBOARD HANDLER

[illegible] RECEIVER.COM [illegible] INT 09h [illegible]

Call With
- AX — B908h

[illegible] INT 09h

Notes [illegible] INT 09h [illegible]

Chain to the old RECEIVER.COM INT 09h handler

See Also: 2F:B908h

INT 2Fh Function BC00h — Windows 3.0, DOS 5+
EGA.SYS — INSTALLATION CHECK

Determine whether or not EGA.SYS has been loaded

Call With
- AX — BC00

Returns
- AL — 00h if not installed / OK to install
  - [illegible] / not OK to install
- BX — 4A4Eh ("JN")

Note: All BC-h are the default values which [illegible] a command line parameter to any value between 80h and FEh

See Also: INT 10 AH=FAh, 2F:BC06h

INT 2Fh Function BC06h — Windows 3.0, DOS 5+
EGA.SYS GET VERSION INFO

Determine which version of EGA.SYS has been loaded

Call With
- AX BC06h

Returns:
- BX 5456h "EV"
- CH major version
- CL minor version
- DI revision

See Also: *INT 10 - EGA,VGA 2F - BC00h*

INT 2Fh Function BF00h — PC LAN
REDIRIFS.EXE INSTALLATION CHECK

Determine whether the IBM LAN Program has installed its redirector and if so, get its segment

Call With
- AX BF00h

Returns
- AL FFh if installed

INT 2Fh Function BF01h — PC LAN
REDIRIFS.EXE UNKNOWN FUNCTION

The purpose of this function has not been determined

Call With
- AX BF01h
- *additional arguments if any unknown*

Returns
- *unknown*

INT 2Fh Function BF80h — PC LAN
REDIR SYS SET REDIRIFS ENTRY POINT

Specify the address of the redirector's entry point for IBM LAN Program

Call With
- AX BF80h
- ES:DI address of FAR routine in DOS to call for IBM LAN Program

Returns:
- AL 00h
- ES:DI pointer to internal workspace

Note: When a redirector is installed, DOS will call the redirector's entry point for the specified subfunctions

INT 30h — DOS 1+
FAR JMP instruction for CP/M-style calls

This interrupt is used by MS-DOS and CP/M programs to perform a FAR call to the DOS dispatcher. It is equivalent to a CALL 0005h. Programs should not use this interrupt directly, but should instead use the CALL 0005h method. CP/M programs may not be loaded into the DOS transient area (TPA) or the DOS

[illegible] PSP 0000h [illegible] if the PSP was created on the EXEC call 21h/4Bh
See Also: 21h/26h

INT 31h — DOS 1+
OVERWRITTEN BY CP/M JUMP INSTRUCTION IN INT 30h

[illegible] INT 31h [illegible] DOS [illegible] DPMI services detailed in the full list on the accompanying disk

Notes: [illegible] DPMI functions which are undocumented

[illegible]
0E05h [illegible] lock selector
[illegible] paging candidate
discard pages

[illegible] information see the interrupt list on disk and *[illegible] and Windows*, chapter 4

INT 67h Function FFA5h — Microsoft EMM386.EXE v4.20+
EMM386 INSTALLATION CHECK

Call With
AX FFA5h

Returns
AX 845Ah if loaded
CX pointer to API entry point

Notes [illegible] EMS [illegible]
[illegible] is at offset 14h

Call API entry point with:
AH 00h [illegible]
Returns
AH status
bit 0 not active (OFF)
bit 1 in "Auto" mode
AH 01h set memory manager state
AL new state (00h ON, 01h OFF, 02h AUTO)
AH 02h Weitek coprocessor support
AL subfunction
00h get Weitek support state
Returns
AL status
bit 0 Weitek coprocessor is present
bit 1 Weitek support is enabled
01h turn on Weitek support
02h turn off Weitek support

— v4.20-4.41 only —
AH 03h Windows support
AL subfunction (00h-01h)
AL [illegible] 21h/09
AH [illegible] EMM386 on the DOS prompt

Glossary

The following list is a partial and somewhat random list of words, terms and abbreviations used throughout this book. *See also* cross-references to "see also" the italicized terms. XX/YY and XX/YYYY means to see the entry for INT XXh AH=YYh or XX YYYYh in the appendix on Undocumented DOS Functions and Data Structures.

A20 On 80286 and higher processors, the A20 address line controls access to the first megabyte of extended memory; address 1 0020 0000h. For compatibility with "address wraparound" on the older 8088 processor, 286+ processors leave A20 disabled. However, to access the *HMA* needed by DOS 5+HIGH, A20 must be enabled. See chapter 6.

ASCIZ A zero-terminated ASCII string, such as: A B C 00h

BPB The BIOS Parameter Block stores the low-level layout of a drive. See 21/53 and chapter 8.

CDS The Current Directory Structure for a drive stores the current directory, type, and other information about a logical drive. See 21/52 and chapter 8.

Chicago Microsoft's forthcoming desktop operating system, incorporating DOS 7 and Windows 4, includes long filenames, threads, pre-emptive multitasking, and other features. See 21/4302, 21/71, 21/72, and chapter 8.

Conventional memory Memory below one megabyte (100000h) immediately accessible by a *real mode* program. Contrast *extended memory*.

DOS extender Software that provides INT 21h and other DOS services in protected mode, creating the illusion that MS DOS is a protected mode operating system. Windows contains a DOS extender. See chapter 3.

DOSMGR The component of Windows Enhanced mode responsible for interfacing with MS DOS. DOSMGR also provides the Enhanced mode *DOS extender*. See 21/1607, chapter 1, and chapter 3.

DPB The DOS Drive Parameter Block stores the description of the media layout for a logical drive, as well as some bookkeeping information. See 21/32, 21/52, and chapter 8.

DblSpace DoubleSpace provides on-the-fly disk compression in MS DOS 6.0 and higher. See 2F/4A11 and chapter 8.

DPL The DOS Parameter List is used to pass arguments to SHARE and network redirectors. See 21/5D00.

DPMI DOS programs can use the DOS Protected Mode Interface to switch themselves into protected mode. Once in protected mode, they can use DPMI INT 31h services to communicate back to real mode. In Windows Enhanced mode, DPMI services are provided by the *VMM*. See chapter 3.

DR DOS DR DOS 5 and 6 were DOS workalikes produced by Digital Research, later bought by Novell. DR DOS 6 has been renamed Novell DOS 7. See 21/4452 and chapter 4

DTA The Disk Transfer Address indicates where functions which do not take an explicit data address will read or store data. Although the name implies that only disk accesses use this address, other functions (such as exec) do. See 21/41 for the FindFirst/FindNext DTA format

Extended memory Memory above one megabyte (100000h) usually accessible only from a *protected mode* program. XMS provides services that allow a real mode program to access extended memory

FAT The File Allocation Table of a disk which records the clusters that are in use. See chapter 8

FCB A File Control Block which is used by DOS 1.x functions to record the state of an open file. See 21/3. Since an FCB resides in an application's own address space, DOS maintains internal System FCBs (also called SFTs or SFBs). See 21/52 and chapter 8

File handle An index into a *JFT*

HMA The High Memory Area is a sliver of extended memory just under 64k bytes, between addresses 100001 and 110310 (FFFFh:0010h and 10FFEFh) that is accessible from real mode on 80286 and higher processors. Real mode programs access the HMA with an address segment of FFFFh. The HMA is only accessible if the A20 address line is enabled. See 21/4A01 and 21/4A02

IFS An Installable File System which allows non-DOS format media to be used by DOS. In most ways, an IFS appears similar to a networked drive, although an IFS would typically be local rather than remote. The 21/1153 IFS interface was for DOS 4.x only. DOS 3, DOS 5, and DOS 6 use 21/11 for the network redirector interface. *Win-nt* will have a documented IFSMGR interface

JFT The Job File Table (also called Open File Table) usually stored in a program's *PSP*, which translates file handles into *SFT* indices. See 21/26 and chapter 8

LoL List of Lists; see SysVars

MCB A Memory Control Block or ARENA contains the size and owner of a conventional memory allocation. See 21/52, and chapter 7

MZ Initials of Mark Zbikowski (5A4Dh) used as a signature for executable files. DOS also uses the letters M and Z as signatures for *MCBs*

NCB A Network Control Block used to pass requests to NETBIOS and receive status information from the NETBIOS handler. See INT 5C/AH=00h in the interrupt list on disk

NETX Generic name for NetWare workstation shell (NET3.EXE, NET4.EXE, NET5.EXE, etc.), which takes over the INT 21h interface. See chapter 4

Protected mode Native mode of the 80286 and higher microprocessors, protected mode provides many of the immediately addressable access to memory above one megabyte. However, most 286+ DOS applications still spend much of their time in *real mode*. See chapter 3

PSP The Program Segment Prefix is a 256 byte data area prepended to a program when it is loaded. It contains the command line with which the program was invoked, a pointer to the *JFT* (and generally the JFT itself), the segment address of the program's environment, and a variety of housekeeping information for DOS. See also 21/26 and chapters 7 and 10

Real mode The native mode of the Intel 8086 and 8088 microprocessors, limited to one megabyte of immediately addressable memory. 80286 and higher machines can emulate real mode, and in fact spend much of their time doing so. MS-DOS is a real mode operating system. See chapter 3.

SDA The DOS Swappable Data Area, containing many (though not all) of the variables used internally by DOS to record the state of a function call in progress. See 21-5D06, 21-5D0B, and chapters 8 and 9.

SFT A System File Table maintains the state of an open file for the DOS 2+ handle functions, just as an *FCB* maintains the state for DOS 1.x functions. See 21-52 and chapter 8. SFT-like entries are also used for System FCBs.

SysVars Also known as the "List of Lists", the SysVars is a DOS internal data structure containing far pointers to many other DOS internal structures, including the CDS, SFT, and so on. See 21-52.

TSR A program that calls INT 27h, Terminate and Stay Resident, or 21-31, Keep Program. See chapter 9.

UMB An Upper Memory Block is an MCB that resides in a PC's "upper memory," the area between addresses A0000h and FFFFFh normally reserved for adapters. Expanded memory managers, including EMM386 or DOS 5 and higher, can allocate UMBs for use by DOS software. Unlike the HMA, UMBs are always accessible in real mode.

V86, VM, VMM Virtual 8086 mode is provided by Intel 80386 and higher processors to emulate one or more 8088-like sessions. Each such session is called a Virtual Machine, VM. A VM can also include a protected mode component. x86 memory managers such as EMM386, QEMM, and 386MAX, and multitaskers such as Windows Enhanced mode or MS-DOS 4 on x86 real. All interrupts in a real mode software running in V86 mode are handled by a 32-bit protected mode program called a Virtual Machine Monitor, VMM. The VMM can emulate the interrupt function and/or reflect the interrupt back to V86 mode. In Windows Enhanced mode, the VMM is contained inside WIN386.EXE and works in conjunction with VxDs. In Chicago, the VMM is contained inside IO.SYS. See chapters 2, 3, and 4.

VxD Virtual Device Drivers are used in Windows Enhanced mode to emulate the behavior of and/or provide a multitasking interface to real mode software such as MS-DOS and the BIOS and devices such as the keyboard, display, disk, mouse, printer, and so on. See 21-1607, 21-1684, and chapters 1 and 3. In DOS 7.x and Windows NT, Virtual Device Drivers are called VDDs; see chapter 4.

ANNOTATED BIBLIOGRAPHY

Phillip M. Adams and Glenn L. Tondo. *Writing DOS Device Drivers in C*. Englewood Cliffs NJ: Prentice Hall, 1990, 385 pp.

Walter Adams and James Brock. *Antitrust Economics on Trial: A Dialogue on the New Laissez-faire*. Princeton NJ: Princeton University Press, 1991. 152 pp. A brief entertaining presentation of the form of an "indictment" against the Chicago School of Economics defense of tying arrangements and other predatory practices discussed in chapter 1 of *Undocumented DOS*. Pages 30-37 on "the predation problem" are particularly useful.

Alfred Aho, Brian Kernighan, and Peter Weinberger. *The AWK Programming Language*. Reading MA: Addison-Wesley, 1988. 210 pp. AWK is an excellent language with which to build disassembly and reverse engineering utilities.

Prabhat K. Andleigh. *UNIX System Architecture*. Englewood Cliffs NJ: Prentice Hall, 1990. 274 pp. Every programmer interested in operating systems should know something about UNIX internals. This is a short introduction with very readable pseudocode. It's a good introduction when trying to tackle Bach's book (see below).

Rick Ayre. "DOS 6 Utilities vs. the Competition: What's the Price of a Free Lunch?" *PC Magazine*, September 14, 1993. On Microsoft's "plot to dominate the utilities arena."

Maurice J. Bach. *The Design of the UNIX Operating System*. Englewood Cliffs NJ: Prentice Hall, 1986, 471 pp.

Richard Belgard. "Appeals Court Reverses Disassembly Decision." *Microprocessor Report*, December 9, 1992. A report on Sega vs. Accolade.

Sudeep Bharati. "Virtual Device Driver Support on Windows NT." Microsoft NT Device Driver Developer's Conference, October 1992.

Douglas Boling. "Background Copying Without DOS 2." *PC Magazine*, 17 January 1989. A DOS multitasker TSR which copies files in the background; discusses INT 28h and Get Set PSP.

Douglas Boling. "Hell Freezes Over: Write Your Next DOS Command Line Interface in ALIAS." *PC Magazine*, 26 December 1989. Discusses 21h, 50h, Get PSP in DOS 2.x; finding COMMAND.COM's PSP and other gems not in the INSTALL statement (new in DOS 4.x).

Douglas Boling. "Strategies and Techniques for Writing State of the Art TSRs that Exploit MS DOS 5." *Microsoft System Journal*, January/February 1992. What TSR writers need to know about interrupts, task switchers, and other new developments.

Douglas Boling. "Quick Boot Your PC and Protect Your Data with BOOTLOG and BOOTLOW." *PC Magazine*, March 30, 1993. Discusses the DOS boot record.

Paul Bonneau. "Windows Questions and Answers." *Windows/DOS Developer's Journal*. This excellent monthly column whose author is now a Microsoft employee often covers topics of importance to DOS programmers. For example, the December 1992 column showed how to license a Windows DOS box's virtual machine (VM) handle from its window handle (HWND).

James W. Brock. "Structural Monopoly, Technological Performance, and Predatory Innovation: Reexamining Standards under Section 2 of the Sherman Act," *American Business Law Journal, Fall 1985*. This look at Kodak's relations with its competitors has some interesting parallels to Microsoft's role in the software industry.

Fred Brooks *The Mythical Man Month: Essays on Software Engineering* Reading MA: Addison Wesley 1975 195 pp. Many developers refer to this book but few seem to have actually read it or paid attention to what Brooks is saying. Note Brooks's warnings regarding David Parnas's then new "information hiding" it presupposed complete documentation. Chapter 15 discusses documentation; note the picture of Stonehenge "the world's largest undocumented computer")

Stan Brown *dos-faq* Frequently Asked Questions list for newsgroup comp.os.msdos.programmer. Available via anonymous FTP from garnet.msen.com. The DOS FAQ contains handy answers to such gotcha questions as "What the heck is DGROUP?" "Will Borland C code and Microsoft C code link together?" "How can I tell if my output has been redirected?," "How do I exceed the 43 or 50 file limit?," "How can I read or write my PC's CMOS memory?," and even "Why won't my code work?"

Ray Duncan (ed.) *Extended Interrupts: A Programmer's Reference to MS-DOS and Third Party Extensions* Reading MA: Addison Wesley 1991. This massive book lists almost any imaginable programming information for the PC sorted by interrupt number. It works off an INT call. Even the DOS interrupt list is available online and is included on the disk accompanying *Undocumented DOS*. *Extended Interrupts* is the definitive tome. In 1994 Addison Wesley will publish the second edition, and a new book, *Network Interrupts*.

David Feher "DOS File Handle Limits" *IBM PC Tech Journal* February 1993. This magazine is now *Windows/DOS Developer's Journal*.

Gwee Mailbox Corporation "MDOS" Machine operating system DOS emulation code. Available by ftp from wsmr-simtel20.army.mil. DOS INT 21h is the interrupt redirection module.

Geoff Chappell *Beginning DOS* Redwood City CA: M&T Books 1989. 337 pp. Assembly language source code for a network based on DOS device drivers.

Geoff Chappell "Spectrum Secrets" *PAF* UK April 1991. A critique of some subtle and not so subtle errors in the first edition of *Undocumented DOS*.

Geoff Chappell *DOS Internals* Reading MA: Addison Wesley 1993. Chappell's book is the natural follow-up to *Undocumented DOS*: covers many topics in more detail and more accurately" but with a slightly different emphasis. Includes extensive coverage of INT 2Fh, the DOSNS redirector, the VxD interface, DOS in ROM, Windows DOS interface, the DBIOS network driver, state machine writing TSRs and device drivers in C, XMS, an entire chapter on the X2 protocol, COMMAND, a close look at HIMEM.SYS, SmartDrive, how to write a DOS 5 compatible IOCTL, and an entire chapter on error codes. An amazing book.

Geoff Chappell "Untangling SMARTDrive" *Dr. Dobb's Journal* January 1992. This article revealed SmartDrive's IOCTL interface. See the SmartDrv 4.x "BARF" interface in the interrupt list on disk.

Laura Chappell, *NetWare Lan Analyst* Sybex Novell Press 1993. Includes a good look at the "guts" of NetWare's NCP, NetWare Core Protocol.

Ray Duncan, Jim Forbes, Mike Hall, Tim Paterson, Michael J. Young, Marc Perkel, Steven Olson, Jeff Sutton *Developing Applications Using DOS*, New York NY: Wiley 1990. 573 pp. This book by twelve IBM employees who were "the lead architects and senior technical staff of the DOS 4.0 system" describes many undocumented DOS features, such as the swappable INT 21h functions 5Dh.

Paul Gustavson "Undocumented DOS and Protected Mode Windows 3" *Dr. Dobb's Journal*, February 1992. Includes a partial list of undocumented SmartDrive IOCTL functions.

Robert Collins "The COMMAND.COM Initialization" *IBM PC Tech Journal* October 1991. This magazine is now the *Windows/DOS Developer's Journal*. Collins uses an ingenious technique to take apart the undocumented COMMAND instructions and has a very good article.

David Cortesi "CP/M-86 vs. MS/DOS: A Technical Comparison." *Dr. Dobb's Journal* 7(1): 1982. An early look at the similarities and differences between CP/M and MS/DOS 1.0.

Helen Custer. *Inside Windows NT*. Redmond WA: Microsoft Press, 1993. 385 pp. As the author puts it, this book explains "exactly how NT (sort of) works." Regardless of whether NT is appropriate for more than a small handful of users, the book never-the-less is essential reading for anyone interested in operating systems and how they work. The chapter on "protected subsystems" discusses virtual DOS machines.

Ralph Davis. *Windows Network Programming: How to Survive in a World of Windows, DOS, and Networks*. Reading MA: Addison-Wesley, 1993. 562 pp. An in-depth look at Windows for Workgroups, NetWare, LAN Manager, and other topics. Chapter 7 covers MFT translation and DPMI.

Harve Deitel and Michael Kogan. *The Design of OS/2*. Reading MA: Addison-Wesley, 1992. 389 pp. Chapter 10 on compatibility covers the OS/2 1.x and 2.x DOS box.

DOS Protected Mode Interface — DPMI Specification. Version 1.0, March 12, 1991. Available from Intel order no. 240977-001. The 1.0 specification is more readable than the 0.9 version (order no. 240763-001), but be aware that 0.9 is what Windows implements.

Ray Duncan. *Advanced MS-DOS Programming*, second edition. Redmond WA: Microsoft Press, 1988. 669 pp. This is the bible of DOS programming, with examples in assembler and C. Includes a discussion of how MS-DOS is loaded.

Ray Duncan, ed. *The MS-DOS Encyclopedia*. Redmond WA: Microsoft Press, 1988. 1,570 pp. Part C of this mammoth textbook, "Customizing MS-DOS," is particularly good, containing chapters on TSRs, exception handlers, hardware interrupt handlers, DOS device and installable device drivers. Includes Richard Wilton's definitive piece on TSR programming. The article on "The Components of MS-DOS" does describe DOS boot sequence.

Ray Duncan et al. *Extending DOS*, second edition. Reading MA: Addison-Wesley, 1992. 538 pp. Discusses DPMI, VCPI, VMS, 16-bit and 32-bit protected mode programming for DOS, DesqView, and other topics.

Ray Duncan. "Microsoft Windows/386: Creating a Virtual Machine Environment." *Microsoft Systems Journal* (September 1988). This remains an excellent description of how Windows/386 enhanced mode provides virtual machines, example DOS boxes on top of a single copy of MS-DOS. Discusses instancing of DOS data structures.

Ray Duncan. "Programming Considerations for MS-DOS 5.0." *PC Magazine* (October 29, 1991): Part 1 and (November 12, 1991): Part 2. How to check the DOS version, access LOLs and the HMA, newly documented INT 21h calls, the task switcher API.

Martin R. Miller. "OS/2 to LAN Man Stepping Stones." Keehan and Patrick H. Wood, eds. *LAN/VAN Networking*. Indianapolis IN: Hayden Books, 1989. pp. 253–284. You wouldn't know it from the title, but this discusses the Server Message Block (SMB) protocol underlying Extended SMB.

Jeff Duntemann and Keith Weiskamp. *PC Techniques: C and Power Tools*. *Techniques and Utilities*. New York NY: Bantam, 1992. 626 pp. Includes schtick, snippets, and tutor for TSR programming, coding DOS from Windows, moving DOS programs to Windows, working with mouse, task options, file date, time manipulation, and music out of a printer.

Grant Edwards. "DOS NetWare Workstation Shell INT 21h Functions." 1998. Unpublished.

Ian Farrell. *Understanding NetWare: A Programmer's Guide to Resource Sharing*. *APIs and Protocols*. Reading MA: Addison-Wesley, 1994. This book will cover the NetWare Core Protocol (NCP), the NetWare Lite API, NETX modification of INT 21h, the IPX interface, server APIs, and so on.

Lance Levy et al. *Jolted Synaptics and Mutilated Economic Analysis and U.S. vs. IBM*, MIT Press, 1985. IBM's view of the U.S. vs. IBM case, makes sobering reading for anyone who thinks there's an open-and-shut case against Microsoft.

Peter Norton and Michael Holmes. *PC Magazine C Tool Notes*. Emeryville CA: Ziff Davis Press, 1993. Chapter 6, "Collecting Program Statistics with INFORMER," presents C source for something sort of like INTRSPY. NETRUN demonstrates NetWare programming, and CHKSTRUC provides C source for a CHKDSK-like utility.

Peter Norton and Michael Holmes. "Optimize Your Disk Drive Efficiency with DEFRAGR," *PC Magazine*, February 24, 1993. Describes the C source code for a defrag utility.

Bruce Webster. "Microeconomics: Not Intervention, Direct Innovation," *InfoWorld*, August 16, 1993. "The positive impact of Microsoft Windows on the fortunes of the entire industry has been profound. ... Windows is starting to look more and more like a real operating engine."

Ostrich Software. *Data Dictionary SDK Reference Manual*. Redmond WA, 1992. 60 pp. The manuals for the Ostrich DOS products written by Steve Jones provide a wealth of information about DOS.

Ostrich Software. *Expanded DOS System Interface Specification and Technical Reference Manual*, Redmond WA, 1992, 155 pp.

Ostrich Software. *Ostrich SDK Reference Manual*. Redmond WA, 1992. 72 pp. Includes source code for the FDISK, FORMAT, CHKDSK, etc.

Steve Gibson. "Microsoft Small Hot Users Decide Which Cards Are Important," *InfoWorld*, September 28, 1992.

Drew Gislason. "Flash File Systems," *Dr. Dobb's Journal*, May 1993. Discusses various approaches to writing DOS file systems on top of flash memory.

Earl Glynn. "Getting a Good Look at How DOS Allocates Your Memory Blocks," *PC Magazine*, 15 June 1990. Describes a MCB walker with Turbo Pascal.

Dmitry Gnazdowsky. "Recreating the DOS Shell," *Programmer's Journal*, May/June 1990. The first two examples show how to create a COMMAND.COM backdoor (INT 21h) from a now-defunct magazine.

Douglas F. Greer. *Industrial Organization and Public Policy*, third edition. New York: Macmillan, 1992. 750 pp. A standard textbook on competition, monopoly, oligopoly, horizontal market-share tests, industry structure, barriers to market entry, predatory practices, vertical market restraints, tie-in sales, pricing, and many other subjects relevant to anyone interested in Microsoft's position within the software industry.

Jim Hyslop. "A DOS Redirector for SCSI CD-ROM," *Dr. Dobb's Journal*, March 1993.

Karen Hazzah. "Easy Interrupt Handling with Non-Resident VxDs," *Windows/DOS Developer's Journal*, June 1994. Uses the interface provided by the VPICD VxD in Windows.

Troy Heber. "DPMI Meets C++," *Dr. Dobb's Journal*, October 1992. An object-oriented abstraction of DPMI.

Alan Jaffe. *Debugging and Variation Under the Shell for MS-DOS*. Redwood City CA: M&T Books, 1986. 450 pp. An excellent explanation, much of it transferable to COMMAND.COM, of how command interpreters work.

Robert L. Ibsen. *PC Magazine Tutorials*. Emeryville CA: Ziff Davis Press, 1992, 344 pp. Source code for a program that reads the MCB chain, the DOS environment, and the FAT, that formats diskettes, manages TSRs, and so on.

Robert L. Ibsen. "How the DOS CLS Command Handles Various Displays," *PC Magazine*, 11 October 1988. "Every once in a while the CLS command DOS sits through a bewildering array of information. Here's a peek behind the scenes at how COMMAND.COM clears the screen", discusses INT 29h.

IBM *Technical Reference: Personal Computer AT*. 1985 (IBM order number 6280070 and supplement 6280099). This is the IBM manual with the full BIOS source code listings. Apparently it's still available for about $200 from 1-800-426-3283.

IBM's OS/2 *2.0 Control Program Programming Guide*. Quite long. 1992. The official IBM documentation includes information on long filenames, extended attributes, FAT, the SEARCHDATA structure, etc.

IBM. *OS/2 Virtual Device Driver Reference*. IBM publication #S10G-6310. Part of the OS/2 2.0 Device Driver Kit (DDK); there's also an OS/2 2.1 DDK.

Intel. *Pentium Processor User's Manual*. 1993. Appendix H, "Advanced Features," refers to the *Supplement to the Pentium Processor User's Manual*, "available with the appropriate non-disclosure agreements in place."

Dave Jewell. "Altered States of DOS." *Program*. NOW (UK), April 1993. Variables in C for editing the master environment.

Steve Jones. "DOS Meets Real Time." *Embedded Systems Programming*, February 1992. How to build a real-time DOS; see also Steve's manuals for General Software's embedded DOS products.

Richard Kitson. "Command Line Tricks of MS-DOS." *Program*. NOW (UK), June 1991. Using the 2F "AE" interface to add new "internal" commands to COMMAND.COM.

Rick Knoblaugh. "Locate Available IRQs with FINDIRQ." *PC Magazine*, September 28, 1993. Describes PIC programming, and a practical aid for waking up the DOS device chain.

Donald Knuth. *Literate Programming*. Stanford CA: Center for the Study of Language and Information, 1992. 368 pp. Knuth treats programs as a new form of literature. Literate programs also require a form of literary criticism. "In a world where writing, apart MS-DOS and Windows, we are still becoming the world's most prevalent operating systems to a form of literacy we can."

Kim Kokkonen. "SNR's Ethics." 1989. Kokkonen provides both Turbo Pascal source code for the following excellent SNR routines: MARK/RELEASE/MARK/MARK/MARK/RELEASE/WATCH/DISABLE/RAMFREE/MAPMEM/DEVICE/FATMEM. Available from CompuServe or the BPROGA forum.

Thomas Kratchowil and Steve Sargo. "An Incompetent Extension Ring to Reduce Costs to Achieve Power over Price." *Yale Law Journal*. December 1986. Read this meta-level interpretation of what Microsoft is trying to achieve with its recent slew of increasingly complex APIs. Or perhaps read Jesper Schmidt's strategies in "Secrets of Professional Windows Programming."

Jim Kyle. "Application Wrappers." *PC Techniques*. June/July 1992. Writing applications that spawn other applications as an alternate way to write TSRs.

Robert Swart and the Waite Group. *Extending MS-DOS: Writing Device Drivers*, second edition. Reading MA: Addison-Wesley, 1992. 560 pp. The second edition is substantially the same as the first (1987) except for the addition of a chapter on CD-ROM device drivers and writing DOS device drivers in C. Does not cover the standard protocol for writing DOS device drivers.

Gene Kozierok. *The Software Developer and Hacker's Total Companion*. Reading MA: Addison-Wesley, 1993. 548 pp. This book/disk package: the disk contains sample viruses, utilities and agreements; discussions of trade secret law, reverse engineering, licensing, shrink-wrap licenses, warranties, and everything a software developer would want to know about the law.

Murray J. Lesser. "Extending COMMAND.COM." *Windows DOS Developer's Journal*. February 1993. The 2F, AE installable command interface.

Gordon Letwin. *Inside OS/2*. Redmond WA: Microsoft Press, 1988. Discusses backwards compatibility, de facto standards, etc.

David Long. "HSR Support in Microsoft Windows Version 3.1." Microsoft Developer Network (MSDN) CD-ROM (see below).

Steven Manes and Paul Andrews. *Gates: How Microsoft's Mogul Reinvented an Industry—and Made Himself the Richest Man in America*. New York: Doubleday, 1993. 534 pp. This is not really the story of Gates's life, which makes it hard to tell if Microsoft's now *that* interesting. Methodology is scientific: every fact or quotation backed up by at least one footnote. This book covers everything from Microsoft's purchase of QDOS to Gates's OEM pricing of DOS to how Murray Sargent and Dave Weise moved Windows to protected mode.

Steven T. Mastrianni. *Writing OS/2 2.0 Device Drivers in C*. New York: Van Nostrand Reinhold, 1993. 410 pp. Chapter 9 discusses OS/2's virtual device drivers (VDDs) and the Virtual DOS Machine (VDM). Very short section for OS/2 2.x, shortage available.

Michael J. Matthews. "The PIF: The Format of Undocumented Windows Structures." *Dr. Dobb's Journal*, July 1989. Program information files (PIFs) are what Windows uses to run "old" (DOS) programs.

Michael McElroy. "Choose CONFIG.SYS Options at Boot." *PC Magazine*, November 29, 1988. Discusses the undocumented DOS CONFIG.SYS buffer.

Michael McElroy. "Running Programs Painlessly." *PC Magazine*, February 16, 1988. Discusses the problems with using INT 2Fh.

Philippe Mercier. *La maîtrise des programmes résidents sous MS DOS*. Marabout, 1990. 410 pp. A handy book on TSRs from Belgium. Did you know that the French for "hotkey" is "touche magique"?

Microprocessor Report. *Undocumented x86 Instructions*. Emeryville, CA: Ziff Davis Press, 1993. A collection of articles on the 286, 386, 486, and Pentium from Michael Slater's brilliant newsletter, *Microprocessor Report*. "The Insider's Guide to Microprocessor Hardware." Includes discussions of undocumented processor instructions and a short section on legal issues. Interesting discussions of the old rumor articles by John Wharton, such as "Quonzo Marketing." Why can't all technical writing be like this?

Microsoft. "API to Identify MS DOS Instance Data." Undated internal document. Describes the DOSMGR call-out API.

Microsoft. *Device Driver Adaptation Guide*. DDK version 3.1, Reymond WA, 1992. Included with the Windows 3.1 Device Driver Kit (DDK). Unfortunately includes an essential appendix on "Windows Interrupt 2Fh Services and Conventions." Why they've put this important stuff in an obscure manual like this is beyond me. There's also a useful chapter on Windows network drivers.

Microsoft Developer Network. MSDN CD-ROM. A must have for any serious DOS or Windows developer, the MSDN CD-ROM includes huge amounts of information that programmers often must look through undocumented. For more information, call 800-759-5474 or 206-936-8661. Here's every article I've ever published in DDJ: "Determining Windows Version," "Mode from MS DOS Apps," "Protected Paging MS DOS Applications," "Global TSR Pop-ups Incompatible with Windows," "Full Screen DOS Apps Slow Timer Messages in Enhanced Mode," "DOS Not Use the MS DOS API in OS/2 or Windows," "Calling a DLL Written for Windows from a TSR for MS DOS," "Finding a TSR in XMS," "Using the Interrupt 2Fh Critical Section Services," "How a TSR Can Serialize Access to Its Data," "DOS Calls in Protected Mode Microsoft Windows," "Access to the Windows Clipboard by DOS Applications," "Windows 3.x Standard Mode and the VCPI," "How Microsoft Windows Uses an MS DOS Mouse Driver," "How to Start a Windows Application Directly from DOS," "Passing File Handles to a TSR for Windows Application." This partial list of titles should make clear that Microsoft documentation sucks. Unfortunately, even the hard DOS programmers can't ignore Windows.

"Microsoft Statement on the Subject of Undocumented APIs." August 31, 1992. Microsoft's news release on Undocumented Windows: "There are undocumented APIs in every major operating system, and application developers routinely make use of them." At the same time, Microsoft issued

"Questions and Answers About Documented and Undocumented APIs." and a readable white paper entitled "Undocumented Functions."

Microsoft. "MS-DOS API Extensions for DPMI Hosts." Version pre-release 0.02. October 31, 1990. A Microsoft confidential document.

Microsoft. *MS-DOS Programmer's Reference*. Redmond WA: Microsoft Press, 1991. 468 pp. The official programming reference for DOS 5. Microsoft advertised this book, which came out shortly after the first edition of *Undocumented DOS*, as "DOS Documented." For the first time, Microsoft officially documented some well-known undocumented functions, which did save many hours. While an essential reference, the book has some curious errors, which I've examined in chapter 1.

Microsoft. *MS-DOS Programmer's Reference*. Redmond WA: Microsoft Press, second edition, 1993. 512 pp. This is the MS-DOS 6.0 version of the programmer's reference. It corrects some of the errors from the DOS 5.0 version and adds chapters on DoubleSpace and MRCI.

Microsoft. OEM Adaptation Kit (OAK): Portable Computing Update for MS-DOS 5. November 1991. Even cash-strapped as the OAK provides a wealth of information on DOS internals, including all sessions of DOS 5 initialization, DBCS vs. epson OEM extensions, all DOS 5 SHARE/ASSIGN/JOIN/SUBST functions, DOS 5 KOM, 21/6Dh, APM, and new IOCTLs for PCMCIA. The source code also includes SYSVARS.ASM, SysInitVars structures, WPA_CHG.INC, DOS patches, DOSTAB.ASM, more DOS patches, PDB.ASM, the PSP structure, CONSTR.ASM, DOS data, MULT.ASM, INT 21h calls, including the network redirector, and OEMNUM.INC, OEM number assignments.

Microsoft. *Virtual Device Adaptation Guide*. VDAG version 3.1. Redmond WA, 1992. Included with the Windows 3.1 Device Driver Kit (DDK), this is the definitive guide to VxDs in 80386 mode. The DDK also includes source code for some of the VxDs listed under Windows.

Microsoft. *Win32s Programmer's Reference* and *Win32 Software Driver Development Guide*. Redmond WA, 1993. Included with the Windows NT DDK, includes "Virtual Device Drivers for MS-DOS Applications that Use Special Hardware."

Microsoft Windows for Workgroups, Resource Kit. Redmond WA, 1992. Where was Microsoft when I needed to know how to produce good documentation? Its "resource kits" are excellent and contain a detailed description of the programmer's implementation.

Microsoft Windows Resource Kit. Redmond WA, 1992. 538 pp.

Microsoft Windows Software Development Kit. SDK. Redmond WA, 1992. The Windows 3.1 version of the SDK is extremely well done and describes many former undocumented features. Its *Programmer's Reference, Volume 1: Overview* contains several chapters that are relevant to DOS programmers, including a chapter on network applications and an extensive section on metafile stamps. "The book is well-organized and the portions are well-indexed." Chapter 6, "Windows Applications with MS-DOS Functions," *Volume 4: Resource Customization*, covers the New Executable (NE) file format.

Microsoft, "Windows 386 Paging Import Specification," formerly Taiwan EMM Import specification document revision 3.10.005, interface version 1.11, August 3, 1991. A Microsoft confidential document.

Ted Mirecki. "DOS Memory Control." *PC Tech Journal*, October 1987, p. 45. A discussion of the favored MCBs from the popular "Tech Notebook" of a now defunct magazine.

Ted Mirecki. "Function 32H of DOS." *PC Tech Journal*, February 1989, pp. 129–133. Describes the structure of the DPB.

Ted Mirecki. "More Handles for New Applications" and "More Handles for Old Applications." *PC Tech Journal*, April 1988, pp. 161–165. Describes the file handle table within the System PSP.

Charles Moore. "Interfacing a Windows Program to a Real Mode Device Driver." *Windows/DOS Developer's Journal*, August 1993.

Peter Norton. *Norton Programming in C*. Que, 1990. Includes a chapter on "Novell's Extended DOS Services."

Peter Norton. "Novell Loading Device Drivers for DOS." *Windows DOS Developer's Journal*, May 1993, pp. 37–43. Another approach to loading device drivers from the command line.

Robert L. Nunnery. *The Law of Computer Technology*. Boston, MA: Warren, Gorham & Lamont, 1985 (also 1991 Cumulative Supplement No. 1). Covers reverse engineering, antitrust, "unfair trade practices," licensing agreements, document retrieval obligations, mass market contracts, warranties, and more.

Peter Norton, Richard Wilton. *Device Drivers*. Reading, MA: Addison-Wesley, 1992. 434 pp. If you just want to control one of the services that the Windows Virtual Machine Manager (VMM) provides for virtual device drivers (VxDs), and don't want to buy the Device Driver Kit (DDK), this is MA (an inexpensive alternative).

Novell. *[illegible] Novell DOS Requester*. February 1993. Explains the limitations of the NETX.EXE shell and describes the new DOS redirector-style "requester" in NetWare 4.x.

Novell. *DR DOS 6.0 Optimization and Customization Tips*. September 1991. Earlier published by Digital Research. Discusses FDOR.DOS 6.0 Version Numbers.

Novell. *DR DOS System Command Line Guide*. DR product #1182-2013-001.

Novell. *NetWare Server Installation and Operation*.

Ewout Oosterhoff. "Making Windows and DOS Programs Talk." *Windows DOS Developer's Journal*, May 1992. Presents several approaches to DOS-Windows communication, including the 2F.1700h clipboard API and a pipe interface VxD.

Walter Oney. "Communication Between Virtual Machines." *Win Dev East 1993*, April 26–30, 1993, Boston, MA. Boston University Corporate Education Center. Another great presentation by Walt Oney, formerly of Rational Systems.

Walter Oney. "Instancing a VSR." *Window Manager*, November 1991. How to use 21.1605h to determine if a VSR is properly instanced for multiple Windows.

Walter Oney. "Porting to DPMI Compatible." *Software Development '91*.

Walter Oney. "Using DPMI to Hook Interrupts in Windows 3." *Dr. Dobb's Journal*, February 1992.

Ordover, Sykes, and Willig. "Predation, Section 2, and Recent Cases: A Reply." *Columbia Law Review*, June 1983.

Ian Peterson. "An Inside Look at MS-DOS." *Byte*, June 1983.

Ian Peterson. "Inside MS-DOS: Device Interface." Schulman et al. *Undocumented DOS*, first edition. Reading, MA: Addison-Wesley, 1990. This chapter was dropped from the second edition, because Microsoft has documented 21.4402h (Load Bat Driver Override). But the official documentation is so sketchy and so full of DOS's programmers' references so wrong that you'll still need this chapter (from the first edition) if you want to do anything with 21.4402h, which is essential to DOS device drivers. DOS's load-driver debugger would also need to be aware of 21.4402h. See Execution Sequence, see Compaq's *DOS Internals*.

Charles Petzold. "Windows Pulls It Off." *Windows*, 28 April 1987. Discusses "the undocumented and strange" INT 2Fh.

Pete Tay. *Software 2000's DOS Extender Developer's Guide*. The writing in this manual is curiously similar in parts to *Undocumented DOS* and *Undocumented Windows*, and contains protected mode versions of several programs that use undocumented DOS.

Matt Pietrek. *Windows Internals: Implementation of the Windows Operation Environment*, Reading, MA: Addison-Wesley, 1993. In chapter 1, Matt shows how Windows boots on top of DOS, with a particularly detailed look at WIN.COM and the Windows KERNEL.

Scott Polk. "Reverse Engineering Reverses." *Upside*, May 1993. A report on the Sega v. Accolade and Nintendo v. Atari cases.

Mike Podanoffsky. *Dissecting DOS: A Code Level Look at the DOS Operating System*, Reading, MA: Addison-Wesley, 1994. Mike is the author of a DOS workalike called RxDOS. This book presents

the assembly language source code for RxDOS providing a unique inside look at how a DOS really works

Jeff Prosise. *DOS 6 Techniques and Utilities*. Emeryville, CA: Ziff Davis Press, 1993. 1035 pp. This massive book for both users and programmers includes chapters on writing TSRs and device drivers.

Jeff Prosise. "Hidden Goodies in DOS 5.0." *PC Magazine*, April 27, 1993. Brief explanation of 21/44A, HMA functions of EMM386.EXE, VCPI support, and of the FDISK /MBR switch.

Jeff Prosise. "How Device Drivers Work." *PC Magazine*, November 28, 1989. Finding the device chain via 21/52.

Jeff Prosise. "The Inner Life of a TSR." *PC Magazine*, August 1990. Discusses the InDOS flag, INT 28h, critical error flag, and Get/Set PSP.

Jeff Prosise. "Instant Access to Directories." *PC Magazine*, 14 April 1987. Excellent discussion of TSR programming; discusses the InDOS flag, INT 28h (including the need not only to hook INT 28h, but also to periodically invoke INT 28h as well), the DOS stacks, DOS critical errors, and hooking the BIOS disk interrupt.

Jeff Prosise. "MS-DOS Q&A." *Microsoft Systems Journal*. Sample columns: May/June 1992 on MCB chain and first UMB; Sept 1992 on SMARTDrive 4 interface; Dec 1992 on making a program load itself high; and on detecting RAM; Jan/Feb March 1993 on 21/44A HMA functions; May 1993 on 21/4803 load-and-no-execute; critical errors and DoubleSpace; June 1993 on 8514/A, Windows, and the critical error flag.

Jeff Prosise. *PC Magazine DOS 6 Developer's Management with Utilities*. Emeryville, CA: Ziff Davis Press, 1993. 405 pp. Includes assembly language source for UMBFILES, FILEMON, HMACALC, GETINSTA, REMOVE, and other utilities.

Jeff Prosise. "Replacing Internal DOS Commands." *PC Magazine*, December 31, 1991. Using the 2F/AE interface.

Jeff Prosise. "Cracking a TSR's New Tricks." *PC Magazine*, 12 June 1990. A brief discussion of the active PSP.

Jeff Prosise. "What EMMExcludes Does." *PC Magazine*, November 12, 1991.

Jeff Prosise. "Unlocking the Mysteries of CHKDSK." *PC Magazine*, May 11, 1993.

Quantum Corporation. *Mace TSR Toolkit*. Capitola, CA: A TSR toolkit for assembly language and C programmers.

Robert Raskin, Charles Petzold, and Stephen Randy Davis. "Taking Up Residence." *PC Magazine*, November 25, 1986. Singing the "TSR blues."

Eric Raymond, ed. *The New Hacker's Dictionary*. Cambridge, MA: MIT Press, 1991. Some will find this book annoying, but it does have good descriptions of several important pieces of programmer lore, such as "You're not expected to understand this" and "Loonix/Smooks."

Tony Rizzo. "MS-DOS CD-ROM Extensions: A Standard Access Method." *Microsoft Systems Journal*, September 1988, pp. 54-60. Describes the Microsoft CD-ROM Extensions (MSCDEX), including its implementation using the DOS network redirector.

Jeff Roberts. "10 Steps to Windows Convenience." *PC Techniques*, February/March 1991. "Take your DOS text-mode applications halfway to Windows."

Wendy Goldman Rohm. "Will the FTC Come to Its Senses About Microsoft's Mischief?" *Upside*, August 1993, pp. 11-27. A weighty piece on Microsoft and the FTC, by the author of a forthcoming book on the subject. One *Undocumented DOS* co-author appears in this article, under the name "Michael Hatch." Includes a telephone interview with Brad Silverberg, Microsoft VP of Systems Software, regarding the XMRD code (see chapter 1). Also see the letters to the editor in *Upside*, October 1993, which were overwhelmingly pro-Microsoft: "In a free market, Microsoft can design its products to do anything it pleases." "What right does the FTC have to regulate Microsoft?," etc.)

Charles Rose. *Programmer's Guide to NetWare*. McGraw Hill, 1990.

Stephen J. Ross. *Principle of Antitrust Law*. Westbury, NY: Foundation Press, 1993, 606 pp. An excellent up-to-date post-Reagan survey of the field, including coverage of "Market Structure and Monopoly Power," Berkey v. Kodak "predatory innovation," Transamerica v. IBM, vertical integration and customary conduct, vertical restraints, tying arrangements, and so on.

Victor Rudnitsky. "Walking the DOS 2 Device Chain." *Dr. Dobb's Journal*, October 1990. An interesting article on traversing the device chain under MS DOS.

Ned Ruggeri. *PC Magic for Turbo Pascal 6.0: Techniques and Utilities*. Emeryville, CA: Ziff Davis, 1991. Objects for accessing undocumented DOS.

Ned Ruggeri. *PC Magic for Turbo Pascal 7.0: Windows Techniques and Utilities*. Emeryville, CA: Ziff Davis, 1992. 1,008 pp. Coverage undocumented DOS from protected mode TPW programs, includes a chapter on "Access to Real Mode."

Richard Sadowsky. "Attaining DOS Enlightenment." *Windows Tech Journal*, April 1992. Accessing undocumented DOS from a protected mode Windows program.

Richard Sadowsky. "Is a Real Eagle Out There." *Windows Tech Journal*, January 1992. From the editor: "You can never tell what these *Windows Tech Journal* articles are about. This one's about moving DPMI protected mode gently into TSR communications with Windows."

Richard Sadowsky. "A Primer on Protected Mode." *Windows Tech Journal*, January 1993. Includes a correction to Sadowsky's January 1992 article.

Ray Seyer. "An Exception Handler for Windows 3." *Dr. Dobb's Journal*, September 1992. Assembly language source code for a VxD, WINX 386.

Murray Sargent and Richard Shoemaker. *The PC from the Inside Out*. Reading, MA: Addison Wesley, 1994. This is the third edition of Sargent and Shoemaker's famous *The IBM PC from the Inside Out*, this new edition with coverage of protected mode, the post IBM PC architecture 386/486/Pentium machines, Windows VxDs, and a host of other topics.

Arno Schaefers. *DOS zur Programmierung: Die endgültige Referenz*. Bonn: Addison Wesley (Germany), 1991. 1124 pp. This massive book includes a lot of material on DR DOS.

Roger J. Schlafly. *Patent, Trade Dress and Intellectual Property*. St. Paul, MN: West Publishing Co., 1986. 272 pp. A quick, cool read that covers competition, trade secrets, the FTC, warranties, and other topics.

Herbert Schildt. "Supercharging TSRs." *Born to Code in C*. Berkeley, CA: Osborne McGraw Hill, 1989. Chapter 3 presents a useful TSR skeleton in Turbo C.

Andrew Schulman. "Accessing the Windows API from the DOS Box." *PC Magazine*, August 1992, Part 1; September 15, 1992, Part 2; and September 29, 1992, Part 3. Using the Windows 2F/17 clipboard API from a DOS program.

Andrew Schulman. "Dr. Programming's Challenge of Windows Protected Mode." *PC Magazine*, June 25, 1991. Accessing undocumented DOS from a protected mode Windows program, using DPMI and some undocumented Windows API calls.

Andrew Schulman. "Go Ahead and Do Anything with 32-bit Virtual Device Drivers for Windows." *Microsoft Systems Journal*, October 1992. Describes VxD APIs accessible via 2F/1684.

Andrew Schulman. "Exploring Advanced Paged Virtual Memory in Windows Enhanced Mode." *Microsoft System Journal*, December 1992. Discusses DPMI and VxDs.

Andrew Schulman. "Call VxD Functions and VMM Services Easily Using Our Generic VxD." *Microsoft System Journal*, February 1993. This article describes in more detail the generic VxD used in *Undocumented DOS*, chapter 3.

Andrew Schulman. "Walking the VxD Chain in Windows and Chicago." *Dr. Dobb's Journal*, December 1993.

Andrew Schulman, David Maxey, and Matt Pietrek. *Undocumented Windows*. Reading, MA: Addison Wesley, 1992. 715 pp. By showing that Windows is just a fancy looking DOS extender, in many

ways reanalyze a new version of DOS, *Undocumented Windows* should give even the most die-hard DOS fanatic "I don't do Windows" a reason to look at Windows.

Larry Seltzer. "Long File Names are Not TSR Issues: Hope for Future DOS." *PC Week*, September 20, 1993. An advance peek at the implementation of long filenames in Chicago.

Mike Speed. "The Undocumented LAN Manager and Named Pipe APIs for DOS and Windows," *Dr. Dobb's Journal*, April 1993. A survey of the 21 51 calls supported by LAN Manager, the named pipe calls are supported by other networks including NetWare.

Barry Simon. "Providing Program Access to the Real DOS Environment." *PC Magazine*, 28 November 1989, pp. 309–334. Discusses the three execution environments: the real or native environment, the program environment, and the protected environment.

Bob Sliska, Eric Straub, and Richard Freedman. "Inside MS-DOS 6." *Byte*, July 1993. Three Microsoft developers provide a good overview of DoubleSpace internal data structures, though they fail to mention Vertisoft, who developed DoubleSpace a full year before.

South Mountain Software. "*Resident C*." *User's Manual*. Orange, NJ, 1991. 112 pp. A succinct manual for South Mountain's TSR library, with a good explanation of a TSR "theory." Also see South Mountain's TSRUtils and Hold Everything libraries.

Stac Electronics. *Stacker 2.0 for Users Guide*. Appendix B: "Programming with Stacker." Discontinued, not included in later versions of the Stacker user's guide, a description of a Stacker API is available on CompuServe (GO STAC).

Al Stevens. *Turbo C: Memory Resident Utilities, Screen I/O, and Programming Techniques*. Portland, OR: MIS Press, 1988. 315 pp. Chapter 11: "Memory Resident Programs," and Chapter 12: "Building Turbo C Memory Resident Programs," present a TSR skeleton. The author's later *Extended Turbo C*. Portland, OR: MIS Press, 1989. 418 pp., contains an improved TSR skeleton plus a fascinating TSR sweep manager.

John Switzer. "Closing DOS's Backdoor." *Dr. Dobb's Journal*, October 1990. Explains a bizarre quirk in the DOS Device I/O Function 21 13, with details on the INT 30h and INT 31h alternate function dispatchers.

Pawel Szczerbina. "The NetWare Core Protocol (NCP)." *Dr. Dobb's Journal*, November 1993.

Andrew S. Tanenbaum. *Modern Operating Systems*. Englewood Cliffs, NJ: Prentice Hall, 1993. Another great book by Tanenbaum.

Andrew S. Tanenbaum. *Operating Systems: Design and Implementation*. Englewood Cliffs, NJ: Prentice Hall, 1987. 719 pp. A superb operating systems textbook, with special focus on the important topics, not the fads, source, and less on scheduling algorithms. Includes C source code for MINIX.

David J. Taylor. "Less Filling, Tastes Great: A Programmer's Survey of MS-DOS Version 5," *Microsoft Systems Journal*, July 1991. See correction in *MSJ*, November/December 1991, p. 16. Includes a discussion of IBM's proposed protocol for interrupt chaining.

David Thielen. "Safer Functions for Working with MS-DOS Files," *Microsoft Systems Journal*, July/August 1992.

David Thielen and Bryan Woodruff. *Writing Windows Virtual Device Drivers*. Reading, MA: Addison-Wesley, 1993. The accompanying disk includes Microsoft's VxD Tutor. See also Thielen's series on VxDs in *Windows/DOS Developer's Journal*, March 1992–August 1992.

Jean Tirole. *The Theory of Industrial Organization*. Cambridge, MA: MIT Press, 1992. 479 pp. Whoever ponders Microsoft's role in the software industry is actually asking a question about "industrial organization." The math in this book is very difficult, but the material on "vertical arrangements," "network externalities," "lock-in," product differentiation, incompatibilities, standards, and bottlenecks is extremely useful.

Paula Tomlinson. "The VDD Backdoor." *Windows/DOS Developer's Journal*, May 1993. As part of an article on NT device drivers, Tomlinson describes ring transitions via illegal instructions

DOS's. See the letters to the editor in the July 1993 issue pointing up the similarities to IBM's DIAGNOSE instruction thirty years earlier in System 360 and later in VM 360.

Neil Frank. "Creating Virtual DOS on the 386." *Byte*. IBM special edition, Fall 1990. A detailed explanation of V86 mode, virtual machines, and device virtualization.

Geoff Gerfin. "Installing MS DOS Device Drivers from the Command Line." *DDJ*, August 1989, pp. 16-20.

Turbo Power Software. *TSRs and More*. Colorado Springs, CO, 1992. 353 pp. A detailed manual on writing TSRs in Turbo Pascal using TurboPower's library, which comes with complete source code. TSRs Made Easy and Object Professional for Pascal provide similar libraries for Turbo Pascal programmers. Some of the examples are very involved. If you're writing TSRs, you really ought to be using libraries such as these rather than coding directly to the DOS and BIOS services.

Lance Leventhal. *Multiple Virtual DOS Machines: A Better DOS*. In Dick Conklin, ed., *OS/2 Notes and Reference*. NY: Microsoft Press, 1990. Contrasts the OS/2 1.x and 2.x DOS boxes.

Various authors. *Windows Source Disassembly Developer's Journal*. San Jose, CA, 1993. Manual by Andrew Schulman and Brad Van Gilluwe. Includes in-depth discussions of "Understanding VxDs," "Understanding OS/2 Device Drivers," discussions of Windows executable file formats, and several VxDs.

Peter Norton, Richard Wilton. *The Undocumented PC*. Reading, MA: Addison-Wesley, 1993. This book is based on Norton's many years experience of disassembling DOSes. He's the author of the Sourcer disassembler, which was used to produce the disassembling DOSes. Covers BIOS functions, also memory locations, I/O ports, and the CPU. Includes chapters on CPU detection methods adapted from Intel development, the BIOS data area, the hard disk, the keyboard, CMOS, system timers, DMA and DRAM refresh, the interrupt controller, and NMI and system timers.

Ray Duncan, ed. *MS DOS Developer's Guide*, second edition. Indianapolis, IN: Howard W. Sams & Co., 1989. 783 pp. Chapter 5, "Program and Memory Management," chapter 8, "Terminate-and-Stay-Resident Programming," chapter 9, "Installable Device Drivers," and chapter 11, "Disk Layout and File Recovery," all discuss undocumented DOS.

Ray Duncan, ed. *MS DOS Papers*. Indianapolis, IN: Howard W. Sams & Co., 1988. 578 pp. Some of the chapters in several chapters have excellent discussions of undocumented DOS: chapter 6, Raymond J. Michels, "Undocumented MS DOS Functions"; chapter 7, M. Steven Baker, "Safe Memory-Resident Programming: TSR"; and chapter 10, Walter Oney, "Developing MS DOS Device Drivers").

Robert Wahbe, ed. *MS DOS Software Development*, 2nd Edition. Lawrence, KS: R&D Publications, 1990. 239pp.

Al Williams. *DOS and Beyond: Protected Mode*. Reading, MA: Addison-Wesley, 1993. 503 pp. An overview of protected-mode DOS extenders for the purposes of this book. Windows is just another protected-mode DOS extender. Includes DPMI programming, interfacing TSRs to Windows, 32-bit programming.

Al Williams. *DOS 5 Power Programmer's Guide*. Redwood City, CA: M&T Books, 1991. 914 pp. Includes sample code on TSR programming, "Big Real Mode," and a protected-mode DOS extender.

Richard Wilton. "Undocumented and Semi-Supported Interfaces." In Ray Duncan, ed., *MS DOS Encyclopedia*, pp. 347-385. This article carries the note that "Microsoft cannot guarantee that the information in this article will be valid for future versions of MS DOS." Nonetheless, it is probably the definitive article on TSR programming. Interestingly, Microsoft eventually documented all the then-undocumented functions discussed in this article.

Kelly Zytaruk. "The Windows Virtual Machine Control Block." *Dr. Dobb's Journal*, forthcoming in January 1994 (Part 1) and February 1994 (Part 2).

About the Andrew Schulman Programming Series

THE ANDREW SCHULMAN PROGRAMMING SERIES has been designed for PC programmers seeking clarity and direction in a rapidly evolving programming universe. This award-winning series reinforces the idea that a decade of programming experience in MS-DOS need not be abandoned in the brave new age of objects and windows.

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Windows Internals

From the moment I opened this book, I was transformed from a [illegible] programmer to a Windows [illegible] and keep it on the shelf for future reference.

Bob Swanson

Undocumented DOS

[illegible] DOS [illegible]

PC Magazine

[illegible] DOS [illegible]

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Undocumented Windows

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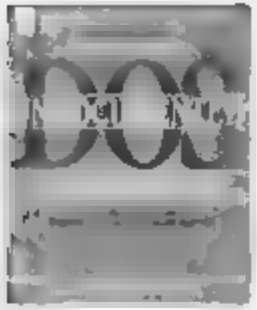

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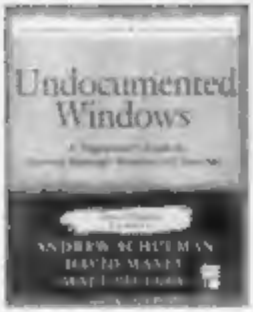

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